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ABSTRACT

This book contains eight papers examining vocational expertise and how best to develop it. The first paper, "Vocational Expertise" (John Stevenson), presents five approaches to developing it. The role of context in patterning cognition is considered in "Authenticity in Workplace Learning Settings" (Stephen Billett). In "Learning in Apprenticeship Courses" (Glen Evans), conceptual and perceptual knowledge and performance are discussed as components of competence. "Train Simulators and the Development of Expertise" (Charlie McKavanagh) analyzes differences between novices and experts from the standpoint of their different approaches to problem solving. The conclusion of "Problem-based Learning in Workshops" (Howard Middleton) is that workshop-based programs are much more effective than teacher-centered technical and further education (TAFE) programs in helping students develop the creative thinking skills needed for the workplace. "Development of Expertise in TAFE Colleges" (John Stevenson, Charlie McKavanagh) explores the nature of teaching and learning in TAFE. "Measuring the Press for Skill Development" (John Stevenson, Charlie McKavanagh, and Alan Evans) discusses the Cognitive Power Holding Questionnaire, and "Pressing TAFE Learners into Far Transfer within a Competency-Based Training (CBT) Framework" (Fred Beven) uses the questionnaire to monitor emphases on different levels of cognitive procedures in a tourism and hospitality program course. All papers contain substantial bibliographies. Fifty-five tables/figures are included. (MN)

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Cognition at work

J STEVENSON (ED.)

The development of vocational expertise

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Contents

Tables

Figures

Introduction 1

1 Vocational expertise 7
John Stevenson

Introduction 7
The nature of expertise 9
The development of expertise 12
Higher order procedures 13
Conceptual understanding 15
Explicit teaching of problem-solving 17
Interaction among cognitive structures 18
Socio-psychological aspects of cognition 20
A comprehensive approach 26
Individual differences 27
Summary 30

2 Authenticity in workplace learning settings 36
Stephen Billett

Introduction 37
The construction of knowledge 37
A socio-cultural base for constructing knowledge 41
Views from related disciplines 43
Cognitive science concept of expertise 44
Transfer 46
Recent studies 47
Implications for the development of vocational expertise 63
Conclusions 68

3 Learning in apprenticeship courses 76
Glen Evans

Introduction 76
The nature of competence 77
The curriculum : progression from novice to expert 81
Approaches to encouraging learning 90
Some empirical studies on promoting learning 94
Summary and conclusion 98

4 Train simulators and the development of expertise 103
Charlie McKavanagh

Introduction 103
Train simulators 105
The nature of expertise 107
Cognitive structures for expertise 110
Information processing 113
Relationship between cognitive structures and information processing 118
Forward and backward reasoning processes 120
Study of a driver driving a simulator 122
Study of train drivers performing a diagnostic task 128
Teaching strategies and learning outcomes 136
Conclusion 137

5 Problem-based learning in workshops 150
Howard Middleton

Introduction 150
Complex problems 151
Creativity 152
Problem-based learning 157
Empirical study 159
Conclusions 165

6 Development of expertise in TAFE colleges 169
John Stevenson & Charlie McKavanagh

Introduction 170
A cognitive model of teaching and learning 171
Desirable characteristics of teaching and learning in TAFE colleges 173
Empirical studies 175
Conclusions 193

7 Measuring the press for skill development 198
John Stevenson, Charlie McKavanagh & Glen Evans

Introduction 198
Influence of settings in activating different cognitive structures 199
Cognitive holding power 202
Items of the cognitive holding power questionnaire 206
Reliability and validity of the cognitive holding power questionnaire (CHPQ) 208
Conclusions 213

8 Pressing TAFE learners into far transfer within a CBT framework 217
Fred Beven

Introduction 217
The Government's CBT agenda 219
Teaching for far transfer 224
Empirical study 229
Conclusions 237

Tables

1.1 Differences in the knowledge of novices and experts
2.1 Frequencies of use of different categories of knowledge (Study 1)
2.2 Mode of skill acquisition by ideal method of learning
2.3 Coal workers' perceptions of reasons for effectiveness of workplace learning
2.4 Knowledge aspects of skilled work
2.5 Perceptions of reasons for effectiveness of workplace learning
2.6 Suggestions for improving workplace learning
4.1 Quotations for forward and backward reasoning
4.2 Backward reasoning section of protocol from the first run
4.3 Forward reasoning section of protocol from the fourth run
4.4 Element codes used in the coding scheme
4.5 Codes and operational definitions of forward and backward categories
4.6 Embedded episode from the diagnostic protocol
5.1 Kruskall Wallis analysis of variance of creativity across groups
5.2 Mann Whitney U test of differences in creativity between Group B and other groups
5.3 Summary of Mann Whitney U test results from Table 5.2
6.1 TAFE classes in the sample
6.2 Instruments
6.3 Categories and coding schedule for teacher and student actions and cognitive structures
6.4 Reading video codes as sentences
6.5 Teacher and student interview questions and coding categories
6.6 Comparison of modal interview responses and top ranking foreground video codes
6.7 Percent time most frequent main foreground actions, overall and by teacher (Study 1)
6.8 Percent time engaged in most frequent main foreground actions by experience of teacher, student type, lesson type, trade area, and college
6.9 Differences between theory and practical classes on sixteen foreground variables as percent of lesson time
6.10 Relative sources of learning content
6.11 Relative emphasis on types of cognitive activity
6.12 Regression of learning sources (predictor variables) on cognitive activity (dependent variables)
6.13 Significant differences between theory and practical classes in terms of cognitive activities and sources of learning content (Study 2)
7.1 Contrasting features of settings with First and Second Order Cognitive Holding Power
7.2 Wording of the thirty items
7.3 Classification of items by Cognitive Holding Power level, activity and wording

7.4 Groups of students studied in TAFE colleges
7.5 Reliabilities of dimensions by group
7.6 Correlations of Cognitive Holding Power scales with observed classroom variables
7.7 Analysis of variance of First and Second Order Cognitive Holding Power
7.8 Regression of sources of learning on First and Second Order Cognitive Holding Power
8.1 Age by group
8.2 Sex by group
8.3 Characteristics of First and Second Order Cognitive Holding Power
8.4 Cognitive Holding Power and gain scores by group
8.5 ANOVAs of First and Second Order Cognitive Holding Power by group
8.6 ANOVAs of Gain Scores 1 and 2 by group
8.7 Linear multiple regression table

Figures

1.1 Cognitive structures for technical expertise
1.2 Abstract and 'life-like' representations of electrical circuits connecting lights in series and parallel
3.1 Expert model of manual metal arc welding
3.2 Flow diagram showing possible elements in welding performance
4.1 Postulated relationship between the problem space and strong and weak methods
4.2 Conceptualisation of forward and backward links
4.3 Roles of cognitive structures and information processing in expertise
4.4 Distribution of forward and backward episodes from the diagnostic protocol
6.1 A cognitive model of teaching and learning relationships
7.1 Orders of procedural knowledge
8.1 Design of study

Introduction

The chapters in this book have been written by staff working in the Centre for Skill Formation Research and Development, Griffith University, together with Glen Evans from The University of Queensland. The chapters examine the question of what is vocational expertise and how can it best be developed. Theoretical discussion of the concepts of competence, expertise, cognition, learning and teaching are discussed and applied in empirical studies of vocational expertise. The studies range across settings - TAFE, coal mines, Queensland Rail, school workshops; and across areas of technical expertise - including electrical, welding, motor mechanics, fitting and machining, butchery, ticketing, train driving, design, electronic process control, carpentry and joinery and some professions. Each chapter examines an aspect of teaching for vocational expertise.

Chapter 1 examines the nature of vocational expertise and discusses five approaches to the development of expertise. It is argued that expertise consists in the ability to coordinate the use of conceptual knowledge, specific skills and general procedures when confronting problematic situations. It is argued further that individual conceptual and procedural knowledge are patterned by communities of practice, in various functional contexts; and that the development of expertise is reliant both on the embedding of knowledge in such contexts and its dis-embedding (abstraction) so that its applicability in new contexts is perceived. It is also argued that individual differences, such as interests, are of considerable importance, but often neglected, in developing vocational expertise. The need for individuals to possess expertise that consists in both conceptual and procedural knowledge and control over their coordination are of considerable importance for coping in vocational contexts of rapid and unexpected change; where plural and changing demands are increasingly made. It is concluded that vocational educators can take more insights from cognitive psychology, with more recognition of differences among individual learners, more attention to developing the ability to control the coordination of different kinds of knowledge, more attention to the embedding and dis-embedding of knowledge in functional contexts, more attention to such social phenomena as the formation of identity through vocational practice, and more attention to prior knowledge and interests.

Stephen Billett, in Chapter 2, pursues the role of context in patterning cognition, by examining effects of communities of practice in fashioning individual cognitive structures. Psychological and socio-cultural views of cognition are contrasted and reconciled, and it is argued that guided learning within an authentic culture of work practice is needed to embed vocational knowledge in the context of its use. Two studies are reported - one of coal workers and the other of a wide range of workers across the range of semi-skilled to professional categories of work, including process and production workers, secretaries, clerks, shop managers, trades-persons, a doctor, a police officer, and a nurse. The findings make it clear that, despite differences in preparation for their vocations, these workers viewed authentic work settings as powerful in developing the attributes needed for expertise in work. They viewed this expertise not only in terms of procedural knowledge, but also in terms of dispositions (values and attitudes). These workers did not appear to perceive as high a value as expected for conceptual knowledge, possibly because of its tacit nature; but placed high value on guidance from others in the work place setting. The chapter concludes that while individuals take the primary active role in learning in authentic settings, the direct and indirect guidance of others is needed to mediate the acquisition of knowledge and dispositions; and that the positive benefits for learning in authentic settings need to be supplemented by the development of structured propositional knowledge which can otherwise be tacit and conceal its value from learners in the work place.

In Chapter 3, Glen Evans examines the nature of competence as both conceptual and perceptual knowledge as well as performance. He argues that it is the knowledge and skill with which a person exercises control over performance that represents real competence. He presents an expert model of manual metal arc welding based on knowledge maps elicited from teachers. An expert model for domestic electrical installation is similarly derived. From these studies, perception and recognition of feedback (indicators) for personal control beliefs and self-involvement, are established as important for regulation of competent performance. The empirical studies provide supporting evidence for the expert models and the utility of indicators (e.g. the nature of the weld pool, the sound of the arc). Yet a focus on these indicators seemed to absent in instruction. Suggestions are made for the encouragement of active learning in workshop settings - promoting a learning ethos; encouraging and providing positive feedback;

using progression in expectations of procedures, concepts, and perception; using monitoring procedures or feedback akin to expert performance; and encouraging apprentices to think actively about their work products and what contributed to the features in these products.

Differences between novices and experts are discussed by Charlie McKavanagh in Chapter 4 in terms of conceptual and procedural knowledge and approaches used by each in problem-solving. He conceptualises problem-solving in terms of the required knowledge and the processes in which the problem-solver engages. Forward and backward reasoning are differentiated, and it is argued that as expertise develops, the expert is more able to use forward reasoning, but needs to return to backward reasoning when totally new situations arise. These ideas are illustrated by studying the problem-solving in which train drivers engage when driving a simulator. Qualitative changes in their thinking are identified as they become more expert; and the implications for developing expertise through vocational education are discussed.

In Chapter 5, Howard Middleton includes in his concept of expertise the generative ability to handle complex, indeterminate situations where no rules apply, and where imagination, improvisation and creativity are required. That is, as well as the ability to engage in near and far transfer, expertise is viewed as involving coming up with new and worthwhile responses to problems encountered in times of change and complexity. He discusses the nature of complex problems and the nature of creativity, and suggests that problem-based learning should develop creativity. An empirical study is presented, which confirms that learners in workshops who are engaged in problem-based learning are more original and elaborative on the Torrance test for creativity. He concludes that the current teacher-centredness of vocational education in TAFE (Chapter 6) is inadequate in the development of the creative thinking skills needed for the changing world of work.

Charlie McKavanagh and I explore the nature of teaching and learning in TAFE in Chapter 6. We present the results of video-recording, interviewing and measurement of characteristics of classes across a large number of classes in five TAFE colleges. The courses involved motor mechanics, carpentry and joinery, butchery, electronic process control and fitting and machining. The classes involved new and experienced teachers, apprentices

and pre-vocational students and theory and workshop sessions. We found that theory classes were largely teacher-centred, with the dominant emphasis on presenting information (rather than skills or problems) to whole classes. On the other hand, practical classes were more diverse in their activities with more teacher interaction with individual students and small groups; and developed a broader range of cognitive structures. However practical classes had a low emphasis on relating new information to existing knowledge and on the organisation of conceptual understanding. It is concluded that more attention to the deepening and structuring of conceptual understanding is warranted, for example, through a greater variety of real world tasks; and that classes need to more concerned with encouraging students to work out problems for themselves, building links between conceptual understanding and procedural knowledge and use of concrete materials (especially in theory classes).

In Chapter 7, Charlie McKavanagh, Glen Evans and I discuss the Cognitive Holding Power Questionnaire. This instrument measures the extent to which learning settings press students into the use of first order (specific) procedures or the use of second order (general) procedures. The differences in press, teacher activities, student activities and cognitive activity in settings with different kinds of cognitive holding power are outlined and the development of the instrument is presented. Statistical data on the reliability and validity of the instrument are provided, based on the use of the instrument in vocational education settings. It is suggested that the measurement of cognitive holding power can assist teachers in monitoring and improving strategies for enhancing learning in vocational education settings, directed at different kinds of learning goals.

In Chapter 8, Fred Beven uses this instrument to monitor emphases on different kinds of cognitive procedures in a ticketing course at the College of Tourism and Hospitality. He relates cognitive holding power to the subsequent abilities of learners to handle a far transfer (problematic) ticketing task. The finding support the utility of pressing learners into solving problems for themselves in developing the capacity for solving of further work place problems. He argues that, even in the context of competency-based training, flawed as it is, there is substantial scope fro vocational educators to press learners into processes that will develop higher order procedural knowledge; and that this is especially important in enhancing their capacity to adapt in the work place.

Together, then, the chapters in this volume present a cognitive view of vocational expertise as involving:

- conceptual understanding
- specific skills with ability to perceive indicators of competent performance
- higher order procedural knowledge such as problem-solving, monitoring and regulation
- the capacity to generate original and worthwhile responses to complex and ill-defined situations
- control over the coordination of different kinds of knowledge in new and unfamiliar problematic situations.

It is argued that, as expertise develops, links are established between conceptual understanding and procedural knowledge; and that these capacities enable the solution of new, unfamiliar and complex problems through the use of forward reasoning from a conceptual base, together with the automatic execution of specific skills, subject to feedback and regulation. It is suggested that the development of such expertise can be enhanced if attention is given to:

- embedding conceptual and procedural knowledge development in functional contexts with authentic characteristics
- focusing more on individual differences, interests, prior knowledge, dispositions and the attributes needed in cultures of practice; giving more explicit attention to affective aspects of vocational expertise
- developing procedural knowledge in a variety of functional contexts, and using these experiences as opportunities to dis-embed principles as conceptual understanding
- focusing more on the organisation and structuring of conceptual understanding
- making feedback indicators explicit to accelerate progression to expertise, and making explicit the relationships among conceptual understanding, perceptual feedback, skill and progressive development of expert performance
- moving from teacher-centred information giving to student-centred active engagement in problem-solving and reflection

- providing opportunities for learners to engage actively in deducing/examining these relationships
- pressing learners into solving problems themselves.

Evidence, to support these concepts and suggestions, is adduced from a variety of empirical studies and suggestions for further research are made. The chapters argue for a view of expertise that is broader and deeper than the concept of competence that is being implemented in competency-based training. To achieve the kind of expertise that is needed in the work place, then, there are considerable challenges for vocational educators. It is hoped that this volume will assist in fashioning productive approaches for teaching and learning.

John Stevenson

1 Vocational expertise

John Stevenson, Griffith University

Abstract *In this chapter, it is argued that vocational educators can take more insights from cognitive psychology in fashioning teaching and learning; and that this requires greater recognition of the differences among learners, a greater focus on some aspects of both propositional and procedural knowledge, more attention to the complementarity needed in the development of propositional and procedural knowledge, more attention to the interests and prior knowledge of learners and greater attention to methods for introducing learners into communities of practice. Some of the implications for vocational education of our current understanding in the field of cognitive psychology relate to emphases needed on different kinds of cognitive structures; teaching and learning approaches needed in developing inter-relationships among those structures and their dis-embedding from particular contexts; instructional design and the development of materials to develop appropriate learning experiences.*

Introduction

In this chapter, ways are explored for applying contemporary learning theory to the improvement of vocational education and training. By vocational education and training is meant any learning aimed at improving a person's ability to perform in the work place. It is recognised that this learning can be on-the-job, or off-the-job or some combination of the two; in a college, in an organisation or at home; and be called training or teaching. Whatever the learning or wherever it takes place, there are important ways in which our current knowledge about learning processes can help to improve practices directed at preparing people for expert performance in work. In the remainder of the chapter, I shall refer to all forms of training and vocational education, simply, as vocational education. I will also take teaching and learning to refer to the activities of those facilitating the learning and those undertaking it, respectively.

The demands of the work place have undergone substantial change over the last decade. According to Laur-Ernst (1992), emphases on flexibility,

quality, shortened production times, innovation and customer needs compel a re-consideration of the capacities needed by those who work in the context of new management expectations. Each individual, she argues, needs to be able to 'handle complex, indeterminate situations to which no rules apply; ...(use) imagination, improvisation, and creativity in solving problems...; (and) react quickly to changes in tasks, restructuring measures, new types of process design etc and adapt or develop their own competence...'(p 37). These demands indicate the need for approaches to teaching and learning that develop the required abilities.

The last decade has been characterised by parallel, but related studies of apprenticeship, workplace learning and everyday cognition that have led to substantial advances in learning theory. For example, the benefits of using the metaphor of apprenticeship learning has enabled Collins, Brown and Newman (1989) to draw together related research in reading, writing and mathematics to develop a theoretical framework for teaching and learning. Similarly, it has been studies of dairy workers 'abilities to make mathematical computations (Scribner, 1984), the ways in which Liberian tailors (Goody, 1989) learn their trade, and Yucatan midwives (Jordan, 1989) acquire both their expertise and their identity, that have enabled such theoretical advances as the conceptualisation of situated learning as legitimate peripheral participation in communities of practice (Lave & Wenger, 1991). Further, studies of apprenticeship have been used by Gott (1989) to identify the importance of being able to co-ordinate procedural, device and strategic knowledge in adaptive opportunistic reasoning performance.

The irony for vocational education of this situation is that studies of cognitive development in vocations is leading reforms in general education, but the full import of the theoretical advances is not being applied in vocational education itself. In vocational education policy, there is growing recognition of the importance of situated learning. For example, the advocates of competency-based training argue that teaching and assessment are best done in the work place (The National Training Board, 1992). However, important cognitive structures, important aspects of learning processes, differences among learners, and important features of learning settings seem not to be understood. It is as though the belief in policy documents is that it is sufficient to create a situation with the physical characteristics of the workplace, and a learner will automatically be pressed

into technical expertise. Similarly there is provision for recognition of prior learning, but no cognisance taken of the relationships among interest, prior knowledge and new learning. My concern is that some of the research findings of cognitive psychology seem to be selectively applied in vocational education, while other important knowledge about learning is ignored.

In this chapter, it is argued that vocational educators should take more insights from cognitive psychology in fashioning teaching and learning; and that this requires greater recognition of the differences among learners, a greater focus on some aspects of both propositional and procedural knowledge, more attention to the complementarity needed in the development of conceptual and procedural knowledge, more attention to the interests and prior knowledge of learners and greater attention to methods for introducing learners into communities of practice.

The nature of expertise

Even in the narrow aspect of vocational education which is concerned with *technical expertise*, learners need a wide range of abilities conceptualised variously as personal, generic and specific capacities, in order to be capable in work. In this chapter, I want to confine attention to technical expertise, ignoring the problematic nature of such a conception of vocational education (For more on this, see Stevenson, 1993a, 1993b). *Technical expertise* is defined here as the ability not only to perform routine technical skills, but also to:

- generate and evaluate skilled performance as technical tasks become complex and as situations and processes change,
- reason and solve technical problems,
- be strategic,
- innovate and
- adapt.

That is, it is defined to included not only what Royer (1979) calls *near* transfer, but also what he calls *far transfer*. Royer (1979) differentiated transfer in two ways — *specific* versus *non-specific* transfer and *near* versus *far* transfer. By specific transfer, he meant transfer which occurs when there is clear similarity between the stimulus elements in the original learning

and the transfer task. Non-specific transfer occurs when there are no obvious shared elements. Royer also drew on Mayer's (1974) differentiation of *near* and *far* transfer. According to Royer, near transfer occurs when the stimulus complex for the new event is very similar to that for the original learning event; far transfer occurs when the stimulus complexes are somewhat different. Although Royer's differentiations are imprecise, they suggest that different cognitive structures may be utilised for different transfer tasks.

The need for far transfer is implicit in the skills identified for the work place by the US Department of Labour (The Secretary's Commission on Achieving Necessary Skills, 1992), the Mayer Committee (Mayer, 1992), and the National Council for Vocational Qualifications in the United Kingdom (see Mayer, 1992). They are also involved, to some extent, in some of the skills emphasised by the National Training Board (1992) as task management skills, contingency management skills, and work role / environment skills. However, the emphasis in the National Training Board's definitions of these skills seems to be on aspects of work roles that lend themselves to pre-specification. It is almost as though it is possible for designers of trainer programmes to predict all the kinds of breakdowns in routine and contingencies that will occur, with some certainty, explicitly train for them, and then assess competence as though it connoted expertise.

Let's look at technical expertise, as I have defined it. According to Gott (1989), the knowledge needed for real-world tasks is:

- *procedural* (how-to-do-it knowledge)
- *declarative* (domain) knowledge of the object (system or *device* knowledge)
- *strategic* (how-to-decide-what-to-do-and-when) knowledge (decision rules for organising and controlling procedural and declarative knowledge — enabling opportunistic reasoning).

This conceptualisation is similar to that used by others writing about vocational education where it is argued that declarative or *propositional* knowledge (knowledge 'that'— information, facts, theories, principles, ...) is important for control in cognitive activity (Evans, 1991); and that both specific and higher order procedures are needed for non-routine performance (Stevenson, 1986a, 1991; Stevenson & McKavanagh, 1992a). It is

also similar to Evans' (1993:15) differentiation between 'competency' and 'competence', where he argues that real competence involves a potential to adapt, the use of both procedures and concepts and the use of strategic skills.

According to Gott (1989), while procedural knowledge enables performance of routine tasks, it does not enable non-routine opportunistic performance. This kind of knowledge can be designated *specific procedures*, i.e. procedures for the attainment of specific goals (Stevenson 1986a, 1991), for example, demonstrating a technical skill so that the procedures are explicit and knowable. Familiar examples for trades-persons would include, changing the spark plugs on a motor vehicle, installing a window in a house, turning an object on a lathe or installing a general purpose electrical outlet in a domestic dwelling. According to Gott (1989), procedures can be hierarchically organised. This view is similar to that of Scandura (1981) who has theorised the mechanisms which operate to ensure that only one procedure (condition-action rule) is fired at a time to secure goals.

The limitations that Gott (1989) identifies for specific procedures are as follows:

- Tasks used to develop proficiency are deterministic and algorithmic (cf The National Training Board's (1992) list of important skills, noted above).
- Limitations of working memory impede rote execution as difficulty increases and environmental conditions change.
- Adaptive generative capability requires not only procedural knowledge, but also understanding of when to deploy procedures and why they work.
- It is understanding the rationales behind procedures that allows performance to be adaptive, under altered conditions, and to be reconstructed if procedures are forgotten.
- It is problem-solving activity that is needed for development of new knowledge.

The development of expertise

These are very strong limitations for vocational educators seeking to prepare learners for a changing work place, where adaptation to new materials, processes, equipment, technology, work structures and work environments is a fundamental requirement. It is clearly inadequate to confine attention in vocational education to specific procedures. These limitations have been known in general education for many decades. There have been at least five sets of approaches to overcoming the limitations of specific procedures:

- **The higher order procedures approaches**: those which propose the development of higher order and general procedures, specially those for the solution of new problems (e.g. Collins, Brown & Newman, 1989; Newell & Simon, 1972; Polya, 1954, 1957);
- **The conceptual understanding approaches**: those which advocate the development of deep and structured conceptual knowledge as the basis for recognising and classifying the characteristics of new situations so that they can be understood and handled (e.g. Glaser, 1989; Gott, 1989);
- **The explicit teaching of problem-solving approaches**: those which advocate the explicit teaching of problem solving rules within a domain in order to develop schemata (cognitive structures that enable recognition of problems and their classification with respect to problem-solving rules) and automate rules (e.g. Sweller, 1989) without undue cognitive load and avoiding the inefficiencies of the means-end analyses which characterise discovery methods of teaching;
- **The interactive cognitive structures approaches**: those which advocate that specific procedures, higher order procedures and deep structured conceptual knowledge be developed simultaneously so that rich linkages are developed among them (e.g. Perkins & Salomon, 1989);
- **The socio-psychological approaches**: those which emphasise the socio-cultural dimensions of the conceptual frameworks through which individuals construct and develop solutions for problems e.g. Greeno, 1989; Pea, 1987; Vygotsky and Leontiev (see Davydov, 1993; Wertsch, Minick & Arns, 1984).

Let's consider each of these sets of approaches.

Higher order procedures

Higher order procedures are defined as procedures that enable the achievement of general goals. They are not tied to a specific goal and are sometimes called heuristics — knowing a general way of proceeding in solving new problems. For instance a hairdresser may have the *specific* procedures needed to apply a commercial product to change the colour of client's hair. However, when a client arrives with damaged hair and wants a colour not previously produced by the hairdresser, more *general* procedures are needed to solve this problem. A hierarchy of procedures can be identified according to the generality of the goal that a person wishes to secure (but, as discussed below, the application of general procedures is limited by the conceptual understanding in the domain under consideration).

Based on the theories of Anderson (1982) and Scandura (1981), Stevenson (1986a, 1991) classified procedures into a hierarchy with three categories:

First Order Procedures:	Procedures for the achievement of specific goals e.g hammering a nail, playing a well practised piece of music, solving a physics problem solved many times previously.
Second Order Procedures:	Procedures which operate on specific procedures to achieve more general goals e.g. transformation of existing skills; checking and evaluating one's own cognitive actions; solving problems by dis-aggregating them into sub-problems; finding applicable specific procedures; sequencing them and evaluating how well they will solve the new problem. Examples include working out how to replace casement windows in an old house in an aesthetic manner, interpreting a new piece of music, solving a new kind of physics problem.

Third Order Procedures: Procedures which control cognition by switching between first and second order procedures.

Consider the following example. In acquiring the skill in writing a word in shorthand, learners could have learned in a number of ways. For example, they could have been shown, by the teacher the exact composite outline for the word. In learning to copy this outline, they would be acquiring a specific purpose procedure, directly. On the other hand, learners may have been taught a number of outlines for the individual sounds which, when linked together, in the correct order, would represent the entire word. In this case, learners would not learn by copying an entire outline, but would analyse the word into its components, recall the individual component elements and their linkages, and assemble them in a manner which would represent the entire word. In this case, learners would have utilised second order cognitive procedures to break the word into its components, select applicable outlines for each element, select the correct linkages and assemble the components to form a composite outline.

The procedures which select applicable specific procedures and assemble them in the appropriate order operate upon specific procedures, and for this reason are designated second order procedures. Such second order procedures are utilised to deal with unfamiliar situations. Once a situation is recognised as problematic, second order procedures enable the new situation to be treated as a problem. That is, they enable the novel utilisation of specific procedures which can be combined in new ways to address problematic situations.

As an example of research applying these ideas in vocational education, Stevenson (1986b) designed TAFE learning environments to press learners into using higher order thinking (second order procedures), and studied their abilities to transfer their knowledge to new situations. In these studies, it was found that if students, in initial learning situations, were pressed into solving problems for themselves, then they were less dependent on instructors when adapting to a transfer task. For instance, students learning to dismantle and re-assemble a Borg Warner automatic transmission were more independent in dismantling and re-assembling a Ford automatic transmission. Hairdressing students were more able to

transfer their abilities to cut hair to one style to the problem of cutting hair to a new style.

As reported in Chapter 7, Beven has also examined the use of higher order procedures in vocational education. He used an instrument for measuring the extent to which learners are pressed into using higher order procedures (Stevenson, 1990, 1992), and studied the effects on their performance on a transfer task. He found that learners in classes with more higher order cognitive holding power performed better on transfer tasks in a TAFE travel course.

In their research, Stevenson and McKavanagh (1992b) (also reported in this volume (Chapter 6), found that the TAFE classes that they studied did not generally focus on the development of such higher order procedures.

Conceptual understanding

As an example of approaches that advocate the development of deep and structured conceptual knowledge, Gott (1989) supports the development of device knowledge. She argues that, to perform with understanding and adaptiveness, requires how-it-works knowledge. This knowledge of *device topology* is the key ingredient that influences procedural skill. In their work, Stevenson and McKavanagh (1992b) found that TAFE classes did not emphasise the development of the conceptual understanding that Gott designates device topology.

The strength of Gott's work is that it has led to similar findings in studies as diverse as electronic trouble shooting in the US airforce and medical diagnosis (Gott, 1986, 1988). For instance she has found that experts in electronic systems see more in problem symptoms and have specialised interpretive knowledge. Experts 'knowledge goes beyond the general features of the situation — they are more accurate in knowledge of features that are *not* salient, as well as having a model of the system as a body of inter-related parts (Gott, 1986). In addition, their specialised knowledge is associated with particular procedures for solving given categories or instances of problems.

What is interesting here is that it is not enough to have the understanding necessary to perform a skill. To adapt to new situations, through problem-solving, one needs to access a richly structured conceptual base in order to work out what kind of problem one is confronting, and one needs to have procedures available for each kind of problem. Thus, one indication of a rich conceptual base is the presence of knowledge that is not immediately relevant to the task in question (but would be relevant to a problem of a different kind).

To some extent, Gott has based her work on that of Glaser (1984, 1989) and his co-workers (e.g. Chi, Feltovich & Glaser, 1981) who found that experts tend to pause before tackling new problems. They argue that experts use this time to understand the problem and relate it to conceptual categories of problems which they are able to attack (much like Gott's idea of multiple levels of abstraction). Moreover, Taylor (Taylor, 1991; Taylor & Evans, 1985) has demonstrated that learners with more understanding in a domain are better at solving problems in the domain), indicating that a learner can develop 'potential' procedural knowledge. Thus, a motor mechanic with deep conceptual understanding of hydraulics would have the potential to solve unusual kinds of malfunctions in the hydraulic systems not only of cars, but also of vehicles other than cars (e.g. trucks) with which the mechanic is not yet familiar. From the work of these authors and others (e.g. Glaser, 1989; Scandura, 1981; Shuell, 1990), some differences among novices and experts in terms of conceptual knowledge are summarised in Table 1.1.

Gott also recognised that the development of conceptual knowledge can be more meaningful to the learner if the development of 'device topology' knowledge (knowledge of internal structures) and procedural knowledge are co-ordinated so that use of device models in problem solving is made explicit (See Interactive Cognitive Structures Approach, below). This develops flexibility in reasoning. She claims that this is so because experts reason about devices at multiple levels of abstraction — they can adapt the way in which they perceive tasks to match a level of abstraction which will lead to successful action. Once learners reach expertise, they can evaluate alternative approaches and choose an appropriate level of generality at which to work.

TABLE 1.1: Differences in the knowledge of novices and experts

	Novices	Experts
Knowledge organisation	Conceptually isolated facts	Structured, systematic Coherent chunks Accessible at different levels of *abstraction* More non-salient knowledge
Problem representation	Surface features	Underlying principles Seen in terms of the whole model or system
Knowledge structures	Declarative knowledge, isolated from applicability; general domain-independent problem-solving procedures	Compiled procedures, bound to conditions of applicability or goals

Explicit teaching of problem-solving

Sweller (1989) also emphasises the development of conceptual understanding which he designates *schema acquisition*. (A schema is a cognitive structure in memory which represents knowledge and allows problem recognition). However, Sweller's approach is distinctive in that he argues that the reliance on discovery methods of learning is inefficient. That is, means-end analysis is an inefficient learning device because it directs attention to inappropriate aspects of the problem and imposes a heavy *cognitive load* that interferes with schema acquisition and rule automation. His approach is to teach explicit problem-solving rules and develop schemata through teaching many worked examples.

The effect of Sweller's approach can be related to that advocated by Gott. In both cases, what is sought is the ability to automatically execute a procedure, once a particular kind of problem is recognised. What Gott provides for us is an understanding that these schemata need to be richly inter-connected in a structured way, so that experts can view new problems at multiple levels of abstraction. For instance, the expert does not merely see a faulty light on a control panel; rather, the expert sees this as a part of a whole electrical/electronic system and can consider various ways in which

the whole system and/or parts of the system might cause the fault. An expert can consider various approaches for finding out if this is true and utilise procedures for rectifying the problem, once the cause is known.

Sweller's approach, then, is to teach, directly, the ways in which the causes of a large variety of such malfunctions can be diagnosed. In this way, the learner will begin to classify different causes in a structured way (develop schemata), and learn procedures (automatic rules) for dealing with each kind of malfunction. The keys in this approach are the direct teaching of problem-solving approaches, the use of many examples and the creation of substantial variation among the examples.

Interaction among cognitive structures

The contribution of Perkins and Salomon (1989) is to integrate much of the research discussed above. They advocate the creation of learning situations where there is an intermingling of propositional (a rich knowledge base) and higher order procedural structures (general cognitive skills) so that they become associated. So, in learning a word-processing package, the learner needs many opportunities to solve different kinds of word-processing problems, to reflect on the similarities and differences among these problems and to relate these differences to an understanding of word-processing.

According to these writers, transfer is weak when one relies on the 'low road'(p 22) (i.e. extensive and varied practice of a skill to automaticity). Consider the well-practised tuning of a motor vehicle's engine. This may be practised to automaticity, so that the order of actions is automatic. Yet, even the 'low road' requires conditions of much practice, in a large variety of situations, in order to lead to a high level of mastery and near-automaticity. But even this automaticity is applicable only to like situations, not new and unfamiliar ones. For instance, it is unlikely to transfer to an aircraft, or, without some knowledge of principles, even to heavy earthmoving equipment or trucks. Rather, for what Royer (1979) would call far transfer, the 'high road'(p 22) is required, which depends on deliberate mindful abstraction of principles, and general strategies for their use in problematic situations. So Perkins and Salomon advocate the development of schemata which richly inter-connect (provide an understanding of when

to use) various specific procedures for specific tasks. The importance here of what they argue is that these principles may not automatically be deduced — what is needed is direct effort in ascertaining what the principles are and the development of an understanding of how they apply to different situations or problems. Like Sweller, Perkins and Salomon argue that general heuristics that fail to make contact with a rich domain of specific knowledge are weak. They also argue that when a domain specific knowledge base operates without general heuristics it is useful mainly for routine predictable problems.

According to this set of approaches, then, the problem for vocational education, is to develop not only specific procedures (for routine skills) and higher order procedural knowledge (for the solving of problems, monitoring and evaluation), but also to develop a deep structured domain-specific conceptual understanding, so that new situations can be understood and classified. However, even this is inadequate in developing expertise. It is in controlling the co-ordination of conceptual understanding of problems and procedural knowledge that enables competent handling of new and unfamiliar situations. So, in designing learning experiences, it is necessary to develop skills, develop problem-solving procedures, develop conceptual understanding and develop control over co-ordinating their use in the domain. As Gott (1989) argues, skill acquisition moves from partial to more complete and complex understandings of domain phenomena, procedural subroutines and strategic control structures. An expert's capability to engage in adaptive, opportunistic reasoning involves co-ordination of these three main sources of knowledge: procedural, device (or system) and strategic control knowledge (Figure 1.1). However, in their studies of TAFE colleges, Stevenson and McKavanagh (1992b) found little evidence of deliberate design of TAFE learning environments to achieve rich interaction between procedural and conceptual knowledge.

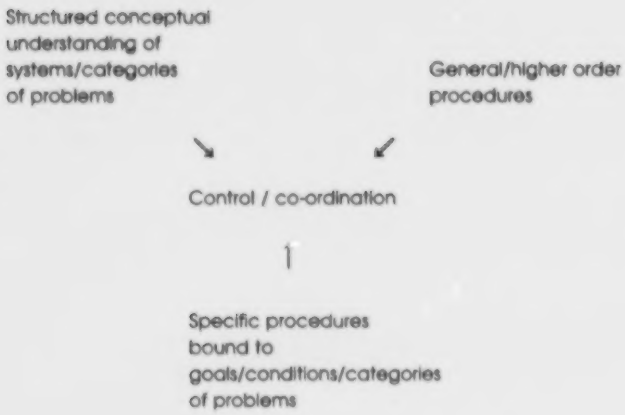
Structured conceptual understanding of systems/categories of problems
General/higher order procedures
Control / co-ordination
Specific procedures bound to goals/conditions/categories of problems

FIGURE 1.1: Cognitive structures for technical expertise

Socio-psychological aspects of cognition

While it would be a substantial advance if vocational (and other) educators emphasised all of the categories of cognitive structures discussed above, and developed learners 'abilities to co-ordinate them, even this would not be adequate unless socio-cultural aspects of cognition were also taken into account. As indicated earlier, it is the ability to transfer which comprises expertise. Transfer, then, is one of the important goals of vocational education in a changing society. However, transfer does not rely merely on possession of cognitive structures from the categories described above. Recent studies have helped us to understand how transfer is also an interpretive and an identity problem.

By analysing cases of learning where transfer is spectacular (e.g. the first five years of life), Pea (1987) has argued that the distinctive features of effective transfer are:

- Learning takes place in *context*: activities are culturally meaningful, and feedback is immediate;

- Learning is effectively *mediated*: there is access to modelling, there is linking, task-relevant information is highlighted and continuity to functional contexts is explicit; and
- Learning is *functional*: this helps develop an understanding of the functions of information for problem-solving.

Pea (1987) perceives transfer as a problem of interpretation and one of appropriacy. Interpretation of a situation requires one to see or read the commonality of elements between the current situation and one for which existing cognitive structures are applicable. The commonality needs to be interpreted; it is not given. For instance, it is not immediately obvious to everyone that there are strong similarities between the Return Key on a computer keyboard and the carriage return on a typewriter; or the steering wheel of a car and the brakes on track-driven heavy earthmoving equipment. Once corresponding devices are seen as similar, this understanding enables the performance of certain actions. Perception of this commonality depends on the structure of conceptual understanding and the meaning assigned to concepts in the structure.

It is not enough for knowledge to be available; relevance needs to be 'seen', by making links between the known and the new. Available knowledge needs to be *accessed*. For instance a person may know that different foods have different densities and water composition, but may not relate these characteristics to the uneven cooking of some foods in a micro-wave oven, unless their attention is directed to the salience of these characteristics to the penetration of food by micro-waves. Once the connection is made, then the person may be able to solve the problem through the placement of the food in the oven, or the protection of some parts of the food with aluminium foil. The reason that a cook, accustomed to convection oven cooking may not solve the problem immediately is simply that the required understanding has not been part of the normal culture of cooking. It is part of the culture of science, and is becoming part of the culture of cooking now that micro-wave cooking has become common in that culture, and various problems of micro-wave cooking have been solved in that culture. Over time, this conceptual understanding will be automatically accessed when dealing with cooking problems. Cooks will have learned to 'read' cooking problems in terms of water content and density of foods rather than in conventional terms.

Another example is the teaching of physical laws of electricity. One may know the properties of resistors connected in parallel and series in an electrical circuit and be able to make accurate calculations when viewing these resistances connected in an electrical circuit diagram. However, one may not immediately be able to relate this abstracted circuit to the real wiring in a house, for the following reasons. In a house a single cable (carrying two wires) connects lights in parallel (Figure 1.2 (a)). Yet, in abstracted circuit diagrams, these wires are shown separately, entering the lights (resistors) from opposite ends (Figure 1.2 (b)). To compound the problem further, usually in a circuit diagram, it is serial resistors that are connected by single lines (Figure 1.2 (c))(cf a single cable, carrying two wires), and a learner may equate the single lines with the single cable, connecting light fittings in parallel in a house.

(a) Circuit diagram with resistances connected in parallel

(b) Actual connections of cables (carrying two wires) between lights in a house

(c) Circuit diagrams with resistances connected in series

FIGURE 1.2: Abstracted and 'life-like' representations of electrical circuits connecting lights in series and parallel

These ideas about the effects of cultures (or communities of practice (Lave and Wenger, 1991)) on transfer are related to those of Vygotsky (see Davydov, 1993; Wertsch et al, 1984) who drew attention to the socio-cultural patterning of understanding, and the need for new learning to occur in the Zone of Proximal Development — the zone between current proficiency and the level of proficiency that can be reached when working with an expert other. It is from considerations such as these that one can understand concerns that knowledge can become 'college-like' in TAFE, or peculiar to the work place culture of a particular firm. The teaching problem is to teach in such a way that not only enables concepts to be matched directly to features of the current work place, but also enables analysis of new work place problems. New problems need to be seen as 'class types'. So, it is not enough to develop concepts and procedures in settings such as a TAFE college or a particular work place. One must also develop the capacity to see the commonalities between that setting and other settings where those concepts and procedures are applicable.

According to Pea, one should:

- ensure knowledge acquisition in functional contexts (cf children's learning in the first five years);
- teach concepts, strategies and skills, in a problem-solving context, where functions are rendered apparent (We can understand better when we see the functional use of that understanding);
- ensure multiple domain-knowledge application examples and experiences in order to decrease welding of knowledge to specific problem contexts (We abstract principles from multiple applications; this helps to structure our understanding; and at each level of understanding, we have a procedure to use);
- bridge instruction across learning settings — teach general principles and help students to see how they work in multiple situations to provide an *index* of our understanding.

Thus, the assessment of performance only in one particular setting is inadequate. The abstraction of principles and their appropriate application, in another setting, which requires far transfer is what demonstrates mastery or expertise. So it is necessary to assess expertise by requiring performance

in different situations, especially unfamiliar ones, where the application of underlying conceptual understanding is required.

Pea also advocates explicit teaching of *cognitive self-management* skills, across curricular projects; and the development of cultures of transfer thinking. The explicit teaching of such procedures as self management of one's cognition is like meta-cognitive approaches to learning (e.g. see Flavell, 1976; Sternberg and Davidson, 1989) and Sweller's (1989) ideas of explicit teaching of problem-solving heuristics. The development of cultures of transfer thinking are seen by Pea as being characterised by self-direction, discussion, and small groups. They involve knowledge in use, they use concepts as tools for understanding, they adopt transfer of thinking as a central goal, and they subject thinking to community reaction and supportive critique.

These ideas are similar to those of Collins, Brown and Newman (1989), who also advocate an approach to teaching and learning which values learning in practice, and involves:

- situated learning (students carry out tasks and solve problems in an environment that reflects the multiple uses to which their knowledge will be put in the future — students understand the purposes of the knowledge, actively use the knowledge, and learn conditions for the application of the knowledge)
- a culture of expert practice (participants actively communicate about and engage in the skills involved in expertise — focus on expert practice, identification and representation to learners of cognitive processes)
- intrinsic motivation
- exploiting co-operation (to provide additional source of scaffolding, give multiple roles to learners, and achieve situated articulation of processes and concepts)
- exploring competition (as a source of comparison)

Some of the most interesting findings, about the sociological aspects of transfer, come from studies across cultures. These studies alert us to the range of factors which impact on a person's growth toward expertise in a culture of practice. By analysing results of studies of cross-cultural learning, Lave and Wenger (1991) argue that not only should learning be situated in a

community of practice, but that the socio-cultural facets of that culture and the person's association with that culture is important. Successful learning seems to be related to identity formation, as learners move from the outer peripheries of a community of practice to full acceptance within the community. Their growth in expertise is associated with a transformation of their identity. Learners are new-comers, in the process of becoming old-timers. Expertise is conceptualised as becoming a member of a community of practice. Knowing, which is comprised of structured conceptual understanding and procedures, consists in concepts and procedures patterned by the culture.

If one applies these ideas to the development of expertise in the work place, the socio-cultural effects of being in that setting when learning, become more apparent. It is not just the concepts and procedures that are important for an apprentice hairdresser or bricklayer to learn. In the process of becoming accepted as a full member of their profession, these workers need to learn the jargon and peculiar techniques of their work place, and be able to conceptualise or re-conceptualise their techniques and concepts in accordance with those of experienced members of that community. As Evans and Butler (1992) found, only when novices had access to jargon about the 'mud pool' of a weld could they move toward the expertise of experienced welders. Evans' and Butler's finding that trade instructors in TAFE colleges were not providing feedback of this kind to apprentices is a common example of how institutionalised teaching becomes abstracted from practice and concepts are no longer patterned by the culture in which they are practised.

The challenge for vocational educators is to access and reproduce salient aspects of communities of practice so that the conceptual and procedural development of learners is meaningful, when they come to work in various communities of practice; and to use situated learning to build identity as well as understanding and technique.

In a longitudinal study, Baxter-Magolda (1993) found that complex thought requires both *relational* (connected, paradigmatic, anchored within oneself, connecting to other people and ideas) and *impersonal* (rational, separate knowing, learning is outside oneself) knowing. She relates the boundaries around oneself and the connections with others to the formation of identity. This formation of identity is associated with a move from accepting

sufficiency of proofs to concerns for a match with experience and developing frameworks i.e. the development of complex thought. Vocational educators have not yet developed ways of recognising the importance of identity formation in the development of technical expertise; or of ways of incorporating this in instructional design.

A comprehensive approach

From the above, it can be concluded that some of the important implications for vocational expertise of our understanding of cognitive structures and processes are:

- There needs to be an emphasis on specific procedures for the accomplishment of predictable work place tasks, groups of tasks, breakdowns and contingencies and for coping with known features of the job role and environment.
- In addition, one needs higher order interpreting, problem-solving and evaluative procedures to deal with new, unfamiliar and unpredictable situations as technology, materials, processes and structures of work change.
- However, specific and higher order procedures are limited by one's conceptual understanding. To be expert, one needs to be able to recognise new problems in terms of underlying principles, rather than surface features; and in terms of whole systems rather than merely isolated component parts. One needs to be able to classify problems and work out a strategy for handling them. In addition, one needs, for each category of problem, procedures that will lead to a solution.
- Conceptual understanding and procedural thinking need to associated. For this to occur, learners need to attack many varied problems, examine the similarities and differences and the implications for appropriate procedures, extract the underlying principles and relate these to their existing conceptual understanding.
- Transfer requires more than the availability of understanding and procedures. It requires understanding and procedures to be accessed in an appropriate way when a problem is encountered. For this to occur, the similarities of features needs

to be perceived, and this perception is bound to cultures. Transfer is best within the culture within which learning has taken place. To overcome the situatedness of understanding and associated procedures, bridging between cultures is needed. Thus, while it is important to embed learning in functional context so that the function is immediately apparent to the learner, it is also important to dis-embed the learning so that the welding to a particular context is overcome. This can be accomplished by taking the concepts and procedures to a variety of functional contexts and making explicit the similarities and differences among concepts and procedures.

Individual differences

In addition to an individual's capacity to read similarities between settings and situations as they attempt to transfer, and in addition to socio-cultural aspects of conceptual and procedural knowledge, there are also other individual factors which affect transfer.

One set of considerations is that of dispositions — one's inclination to engage in activities. As Billett explains (Chapter 2), there is a link among the value a learner places on engaging in an activity, the value they place on knowledge (Goodnow, 1990; Pea, 1987) and the effort that they will expend. According to Pea, the disposition to engage in an activity depends on such affective and motivational factors as self-efficacy, fear of failure, anxiety, intolerance of mistakes and other emotional factors; as well as on socio-cultural aspects of appropriateness and perception of the economy of effort involved.

There has been a renewed interest, within cognitive psychology, in the effects of individual differences on learning. Two sets of individual differences, enjoying considerable research attention, relate to the role of prior knowledge in learning and the role of such motivational factors as student interest on learning. While teachers may have a clear idea of the outcomes they are seeking from instruction, substantial additional knowledge about the learners is needed in order to design and offer meaningful learning experiences.

Tobias (1993) draws attention to the need to take account of affective factors on learning and cognition. He differentiates two kinds of interest: situational and individual. By situational he means interest elicited by the situation — e.g. novelty, intensity, attractiveness; and, by individual, he means relatively enduring preferences e.g. for topics or tasks. From an analysis of the literature on interest and prior knowledge he concluded that:

- 20% of interest is due to prior knowledge;
- interest has an energising effect, stimulating deeper comprehension, arousal of wide network of associations, greater use of mental energy, more personal experience and more pleasant emotions; and
- interest is different from curiosity — interest is related to an energising effect; but curiosity helps to explain attraction, neutrality and avoidance.

The important question is whether interest is important in the development of knowledge; or if the possession of knowledge leads to interest.

Alexander and her co-workers (Alexander, Kulikovich & Jetton, 1993) reviewed 66 studies of the role of subject-matter knowledge and interest. From these studies, they also differentiated situational and individual interest, and found that:

- knowledge and interest increase if educators attend to the nature of the domain;
- as learning proceeds, the importance of domain-related knowledge to subsequent learning increases;
- interest levels stimulate depth of processing; and
- matching student interest and subject matter knowledge has a powerful effect on learning outcomes.

They concluded that one needs to integrate knowledge, interest and situation in designing assessment.

Further, Alexander and her co-workers (Alexander, Jetton & Kulikovich, 1993) have been able to create profiles of learners based on their prior knowledge and levels of interest. These range from those with some background and strong interest who do exceptionally well when recalling

new material, to those with no prior knowledge or interest, who remember little of what they read. They conclude that, within acclimation, competency, and proficiency stages of learning in a domain, there are individuals who vary in how much they know and care; that some individuals advance strongly because of their general processing strategies; and, for others, their prior knowledge diminishes their need for such strategies.

These findings are of particular concern in contemporary vocational education where there is increasing reliance on learner interaction with text. Wade et al (1993) found the following:

- perceived importance of information and ease of comprehension correlate strongly with levels of interest and enjoyment;
- description and concrete detail that enhance visualisation contribute to interest and understanding;
- comparisons and easily understood analogies are effective; and
- information seen as too technical, abstract and irrelevant to purpose was considered uninteresting — similarly learners who regard humour as irrelevant and distracting also regard it as uninteresting.

So, it is not enough to prescribe learning outcomes or learning tasks. Learners 'cognitive development depends on affective and motivational factors, and our knowledge is growing about the relationships between prior knowledge and interest and their effects on learning outcomes. Our knowledge is also growing on how to incorporate these findings in instructional design.

Much of this research on prior knowledge and interest is confirming that our focus in teaching and learner should be on the individual's active construction of knowledge. It cannot be assumed that all learners are alike and will be motivated to move towards pre-specified learning outcomes. Motivation and comprehension are not automatic — they need to be created and nourished. We need to ensure that new learning connects with the learner's previous knowledge and we need to increase the learner's interest on new knowledge through these connections. Some ways of doing this include: situating the learning in settings of authentic practice, building a community of learners, making comprehension easier, highlighting the

importance of salient concepts, and making use of analogies and comparisons.

Summary

Current emphases on learning outcomes in vocational education need to be supplemented by:

- emphases on the wide range of cognitive structures required for technical expertise so that:
  - deep conceptual understanding is developed,
  - concepts are available at multiple levels of abstraction,
  - principles underlying classes of problems can be perceived,
  - procedural knowledge is associated with conceptual knowledge at different levels of abstraction;
- emphases on developing control over the co-ordination of these different kinds of knowledge so that they are available and accessed for far transfer:
  - learning in authentic functional contexts to embed knowledge and relate it to its application,
  - mediation of learning by teachers,
  - application in multiple domains to dis-embed knowledge so that it has the potential to be related to new applications,
  - bridging of applications across settings through identification and application of principles,
  - developing cultures of transfer thinking;
- addressing changes in identity as learners move from peripheral participation in a community of practice (cf functional context) to contextual understanding and proficiency in that community;
- recognising that knowledge is personally constructed and that individual differences in such areas as prior knowledge and

motivational factors such as prior knowledge will affect learning outcomes:

- applying emerging understanding about the effects of interest in stimulating deeper processing and understanding and more personal experiences; exploiting the relationships among interest, prior knowledge and its application; and
- designing learning resources to enhance interest and learning.

Thus, in summary, some of the implications for vocational education of our current understanding in the field of cognitive psychology are:

- emphases on different kinds of cognitive structures;
- approaches to developing control over the co-ordination of these structures and their dis-embedding from particular contexts;
- instructional design and the development of materials to develop learning experiences, appropriate to individual learners.

There are considerable challenges for vocational educators in implementing these emphases and approaches.

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2 Authenticity in workplace learning settings

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Abstract *This chapter describes a basis for considering the development of vocational skills using the workplace as a learning setting. A view of learning is adopted, which emphasises the role of social and cultural context in the construction of knowledge. The broad proposition advanced in the chapter is that learning experiences in workplaces have the potential to develop the knowledge, understanding and dispositions required for skilled vocational practice. In advancing this proposition it is argued that access to guided workplace learning experiences, that are socio-culturally authentic, are an essential ingredient in the development of vocational skills. Moreover it is argued that these learning experiences are more likely to generate the purposeful representations required for problem-solving than would result from substitute experiences.*

Some support for these propositions are found in two recent studies reported in the chapter. The studies, conducted within Queensland industries, produced consistent findings with workers perceiving that specific aspects of authentic learning experiences provided positive learning outcomes. Using these studies the chapter advances three implications for the development of vocational skills. Firstly the development of vocational expertise needs to be conceptualised as a learning experience, not a teaching process. Secondly, learning needs to be embedded in a purposeful socio-cultural context. Thirdly, to facilitate the transfer of learning requires the development of self-management and self-regulation abilities.

The studies also reported workers' perceptions about the utility of dispositional knowledge — attitudes, values and interest — in the securing of skilled vocational performance. The chapter concludes by proposing that instructional processes needs to focus on the activities that learners engage in, the direct and indirect guidance of others, and the significance of the social and physical context of learning.

Introduction

The growing interest in vocational education and the development of a wider range of vocational education settings have brought with them questions about how and where vocational skills can best be learnt. This chapter proposes a basis for the development of vocational skills using the workplace as a learning setting. A view of learning is adopted, which emphasises the role of social and cultural context in the construction of knowledge. It is argued that learning experiences in workplaces have the potential to develop the knowledge, understanding and dispositions required for skilled vocational practice. It is also argued that this development requires access to guided learning experiences in the workplace that are socio-culturally *authentic*, with *authentic activity* being defined as the ordinary, everyday practice of the culture (Brown, Collins & Duguid, 1989).

The chapter reviews pertinent literature and draws upon two recent studies of skilled workers' perceptions of workplace learning. The findings of these studies support the view developed from the literature that guided learning, within an authentic culture of work practice, embeds the development of vocational knowledge and understanding in the context of its use. The chapter concludes by discussing implications of this view of learning for instructional practice within vocational education.

The construction of knowledge

The recognition that learners play an active role in their own development has helped displace behaviourist views that learning is something akin to an empty vessel being filled with knowledge that somehow enables performance. Learning is both active and individual (Posner, 1982). Moreover, knowledge acquired by individuals is not objective or 'given', but is constructed and represented in ways determined by personal dispositions and histories (Belenky et. al. 1986; Dweck & Leggett, 1988; von Glasersfeld, 1987; Greeno 1989). This construction of knowledge is mediated by the social and cultural context in which it is acquired, which includes the socially and culturally derived norms of a *community of practice* (Lave, 1990; Lave & Wenger, 1991). A *community of practice* is defined as a set of

relations among persons, activity and world over time, and in relation to other tangential and overlapping communities of practice (Lave & Wenger,1991:98). The *culture of practice* refers to the activities that comprise and distinguish a practice and the social relations within that practice. These norms and practices are central to the conduct of, and participation in, vocational practice, and, as such, need to be accounted for in learning arrangements aimed at developing vocational knowledge. To examine these ideas, and their application to workplace learning, a review of learning theories within cognitive science is presented and their social and cultural orientations are identified. Firstly, the constructive nature of becoming knowledgable in vocational practice is discussed. Views developed in this section about the processes of learning are then compared with views from related disciplines.

A 'constructive' view of learning emphasises active and interpretative knowledge acquisition, as individuals integrate and extend their knowledge in an effort to maintain its *viability*. The *viability* of knowledge is defined in terms of a 'fit' between the existing internal organisation of individuals' knowledge, based on previous learning and dispositions, and their on-going interaction with the world (von Glasersfeld, 1987). This process is analogous to Piaget's (1966) notion of the learner's quest for equilibrium. Individuals seek to 'make sense' of what they see and experience. The viability of knowledge depends on the fit between the existing knowledge of the individual and the way it reflects what the learner continuously observes and experiences. The structure of knowledge is based on what the individual experiences and how it is interpreted through their filters of interest, values and affect. These interpretations lead to the prioritisation and categorisation of what the learner experiences.

Hence, an individual's representation of knowledge in memory would be unique to that individual, being dependent on their experiences, interests, values and affect. However, although a constructivist view of learning presents an idiosyncratic approach to the organisation of knowledge, this does not necessarily imply a chaotic ordering, which impedes communication with others. Only when individuals' concepts manifestly clash will they fail to be compatible enough to form the basis of communication (von Glasersfeld 1987:7). Moreover, it has been suggested that different interpretations are a necessary part of any social encounter

because, if interpretations were identical, there would be little need to communicate (Newman et al, 1989).

To illustrate this constructive process, consider two individuals acquiring an *understanding about a piece of equipment*, by looking at it, and hearing about it. The task of understanding the purpose and operation of the piece of equipment is likely to be different among learners, given each individual's previous knowledge and experience (Posner, 1982). Understanding might be similar in terms of the equipment's function, where the function is highly visible, whereas understanding may differ about the equipment's operation. For instance, one individual might have developed an understanding about the operation of pistons from a text book diagram, while the other from using a bicycle pump. Although a discussion about the function of the equipment may not reveal differences in understanding, a more detailed interchange about its operation may reveal variation in understanding. That variation might be based on a range of factors, for example, a misunderstanding about what actually makes the equipment operate. Such a situation might be resolved by providing access or insights which helps establish a 'fit', to render the two forms of understanding viable. Yet alternatively, understanding might be based on experience with critical factors of the equipment's operation. In this circumstance, assurances, from someone without such experience, that a particular component is not troublesome are unlikely to be accepted as viable by an individual whose experience with that component has been one of constant breakdowns.

A second dimension of this interpretative view of learning also needs to be taken into account. This relates to the values of the learner. The worth that individuals place on knowing about a piece of equipment will determine whether they will even bother to consider its operation and function. Learning, particularly when it involves undertaking any active thinking, is effortful. As a consequence, the amount of effort expended by individuals in learning something will be related to the value placed on acquiring that knowledge (Goodnow, 1990; Pea, 1987).

How then do knowledge and understanding develop so that communication and engagement in the common practices of a vocation occur? Two perspectives are commonly acknowledged within a constructivist view of learning, the Piagetian and the Vygotskian (Glaser & Bassok, 1989; Rogoff,

1990; Roth and Roychoundhury, 1991). Each perspective makes a valuable contribution to an understanding of cognitive development. However, they can be differentiated by the roles they ascribe to social interaction, in the learning process. They also differ about whether cognitive development is a precursor to, or dependent on, knowledge. Taking the first difference, Piaget proposed that individuals seek to secure equilibrium between antagonistic viewpoints in order to generate viable knowledge (Taylor, 1991). On the other hand, Vygotsky (1978) viewed knowledge as being collaboratively constructed, through a process of joint problem-solving and decision-making. Taking the second difference, Piaget referred to cognitive development in terms of stages, with each stage permitting increasing levels of complexity in the general application of cognitive processes. However, Piaget's notion of development has been challenged by the significant role now being afforded to domain-specific knowledge in thinking and learning (Glaser, 1984), and the failure of general applications of knowledge to be upheld (Carey, 1984; Chi, 1978; Rogoff & Gauvain, 1984). That is, whereas Piaget argued that the development of necessary cognitive structures is a precursor to stage transition and learning, Vygotsky claimed that learning precedes, and makes possible that development (Taylor, 1991).

From the Vygotskian view cognitive development is realised through social interaction which results in the *appropriation* or internalisation of culturally-determined knowledge by the individual (Rogoff, 1990:150). *Appropriation* is defined here as the individualised process of constructing meaning from socially and contextually defined knowledge, using the individual's idiosyncratic structuring of knowledge and understanding. This process has been likened to the intra-individual phase of Piaget's concept of knowledge development (Roth & Roychoundhury, 1991). Rogoff (in press) argues that appropriation and internalisation are not synonymous. She suggests that *internalisation* implies the passing of external knowledge intact from the outside to the inside, whereas, appropriation is premised on how individuals participate actively with, and interpret, external knowledge — 'gaining facility in an activity'(in press:15). This view emphasises again the notion that knowledge is not 'given', but is actively acquired, interpreted and represented by the individual.

Whereas the Piagetian perspective is that learning is essentially self-regulated and intra-individual (within the individual), Vygotsky viewed learning as being social or inter-individual (between individuals), and

emphasised the interaction between cognitive and social activity, a view which is becoming widely accepted (Goodnow, 1990; Newman, et. al., 1989; Rogoff, 1990; Stigler, et al., 1990; Wertsch, 1984). Thus, while much of what has recently been proposed by Glasersfeld (1987) is consonant with Piaget's notion of equilibrium, as learners attempt to integrate new information with what they already know and understand, the explanation is not totally adequate.

The Vygotskian notion of appropriation enables a more comprehensive account of learning, by including the social and cultural mediation of knowledge and understanding, and is therefore used as a basic starting point in this chapter. The choice of approaches has implications for instructional processes. Whereas a Piagetian view of instruction might focus on the actual developmental level of the learner, the Vygotskian view addresses the area of learners' development which can be realised with guidance — the Zone of Proximal Development. Instruction, from this point of view, is a process that seeks to advance the development of the learner rather than being dependent upon the level of development (Vygotsky, 1978). However, as with Piaget's view, this social learning process is not regarded as benign. Appropriation is not simply the enculturation of learners who are helpless to resist. Instead, it is an active encounter between the individual's knowledge and understanding and socially-mediated, culturally-derived knowledge. Thus, as Piaget would argue, it is likely that learners will contest and challenge the externally-derived knowledge with which they are confronted, as they attempt to establish the compatibility of their understanding with what they experience. That contestation is likely to be stronger when existing understanding and beliefs are challenged. Consequently, this learning process is viewed as being problematic, rather than benign (Goodnow, 1990).

A socio-cultural base for constructing knowledge

Vygotsky's view of knowledge construction is founded on two key principles: social relationships and the socio-historical nature of knowledge (Rogoff & Lave, 1984). To consider the significance of a social basis for

learning, it is necessary to acknowledge the contribution of both immediate interpersonal interactions and more distant social and cultural contexts.

Immediate or proximal social relationships, for example between master and apprentice, provide a basis for a collaborative process of problem-solving and decision-making. Rogoff (in press:11) refers to this process as *guided participation*, which is defined as an interpersonal process in which people manage their own roles and those of their social partners, and they collaboratively help to structure situations in which they observe and participate in cultural activities. The relationship between the learner and the 'teacher' (master to novice, parent to child or teacher to student) is socially determined, which influences the nature of what knowledge is shared with the learner and how it is shared. Skilled workers may share with novices only information which they determine to be appropriate — in much the same way that parents may withhold information about personal, financial or sexual matters from their children. The reason for withholding information might be in consideration of novices' limited experience and understanding, with a judgement being made that the learning is outside their Zone of Proximal Development. Alternatively, withholding might be to maintain status in the expert-novice relationship. Collaborative problem-solving might also be made problematic by a learner's lack of interest, and hence reluctance to make the effort required to engage in problem-solving.

The social relationship is also shaped by more distant or distal forms of social organisation, such as social influences, the cultural practices which organise work activities, and associated priorities and values, the nature of the physical setting and the institutional structures of the setting. Even the most apparently solitary task is embedded in social practice (Cadzen 1993) or, as Scribner exemplified, (1992:92)' I think of Marx's example of the lighthouse keeper on solitary watch in the beacon tower as a paragon of social labour'.

Vygotsky's second principle is that knowledge has a socio-historical basis. What is useful or useless, what should be learnt, what is worth passing on to novices and what practice is inappropriate, are the product of a community of practice (Lave, 1990). Cultural practice, having evolved through application and time, is socio-historical in origin. For example, electricians' work and use of tools are based on the requirements of their vocational activities, which have a hierarchy of tasks based on their

complexity. How a particular community of practice guides workers to undertake tasks and use tools is different from other cultures, because the tasks they perform are different (Brown, et al, 1989). For instance, issues to do with safety have a particular significance for electricians and are a central part of the culture of their work practice. It is this socio-historically derived practice that is expected to be appropriated by novices, as has been demonstrated in a range of cross-cultural studies (Lave, 1990; Lave & Wenger, 1991; Rogoff & Lave, 1984; Rogoff & Gauvain, 1989; Rogoff 1990).

In summary, cognitive development from a Vygotskian perspective is through appropriation, as the individual constructs knowledge and understanding from socially-derived norms and practices, through proximal and distal forms of guidance (Rogoff, 1990:150). The appropriated knowledge leads to a more socio-culturally oriented, and less idiosyncratic, structuring of the individual's knowledge, as the personal history and experiences of the individual merge with understanding within a community of practice. It is proposed here that the degree of appropriation is dependent upon the nature of learning experiences. That is, it is likely that the learner will seek justification of viability from experts, others and particularly from their own experiences as they appropriate knowledge.

Views from related disciplines

Support for the view that knowledge is mediated through social and cultural sources is found within other related disciplines, such as ecological psychology, cultural psychology, sociology and anthropology. These disciplines, in contributing to current understanding about learning, have strengthened the concept of a social and cultural basis for acting and thinking. The ecological psychologist Barker (1978) proposed that setting and behaviours are linked and cannot be dismissed as probabilistic. He concluded that environments consist of structured, highly organised phenomena, which are not passive or probabilistic. He argued that these environments are arenas for events, and a causal relationship exists between the environment and behaviour (Schoggen, 1992:78). This view is consistent with those that suggest understanding and knowledge are influenced by the circumstances of their application — their settings.

Work being undertaken from anthropological perspectives is also supportive of a contextual basis of learning, in that cognitive properties are regarded as being embedded in contexts, rather than in isolated minds (Pellissier, 1991:80). The idea that cognition is structured by activity, with cognitive processes being tied to applications, or put more succinctly — that activity structures cognition — also finds support within sociological work (Scribner, 1985). Lave and Wenger (1991) have emphasised the significance of learning processes within a community of practice, which involves novices in increasing levels of participation, as they move from peripheral activities to more complex elements of practice. Moreover, in emphasising the social and cultural basis of practice, it is argued that full participation is more than being technically competent; it is also concerned with being able to function within the community of practice (Lave & Wenger, 1991). Thus, participation requires the possession of understanding, in order to be able to engage in the culture's discourse.

Cognitive science concept of expertise

Despite the similarity of shared concerns between cognitive psychology and the socio-cultural theories of learning, full resonance is still lacking between these bodies of literature. In this section some links between the literatures are advanced, using the concepts of representation and problem-solving, which are acknowledged in both sets of literature as being central to expert performance.

As argued above, the way an individual interprets or represents events and experiences (Posner, 1982) is fundamental to the construction of knowledge. *Representation* is defined as embodiments or interpretations of ideas and can be verbal, pictorial, diagrammatic or physical (Prawat, 1989). The quality of representations has a range of consequences for cognitive activity, particularly because representations are central to complex performance or expertise. For instance, being able to apply skills in novel situations distinguishes experts from novices (Ericsson & Simon, 1984; Wagner & Sternberg, 1986). This requires possession and use of appropriate cognitive structures for solving problems. For instance, experts' abilities to categorise problems effectively are based on how they represent the problem, and this categorisation assists their solution (Glaser, 1984). Cognitive scientists also recognise that which is common between previous experience and problem

states is not 'given' or objective, but is individually interpreted (Gelman & Greeno, 1989; Pea, 1987; Posner, 1982; Prawat, 1989).

Prawat (1989:3) argues that representations play an important role in problem-solving as 'they can give meaning to an abstract concept by highlighting certain properties of the concept', and, in the form of analogies or metaphors, they can facilitate the transfer of knowledge from one domain to another. Extensive prior knowledge and understanding provide a base upon which experts are able to draw when categorising problem states and/or breaking problems down into workable and solvable chunks (Chi, Feltovich & Glaser, 1981). Some parts of a problem will require greater attention than others. More familiar parts can be addressed more easily, even tacitly, freeing the thinking processes to concentrate on the unknown parts of the problem. Representations which are strongly indexed to purposeful applications are those more likely to be recalled and utilised than those which are substitute or artificial (Brown, et al, 1989). Consequently, socio-culturally authentic learning experiences where applications are clear are more likely to generate purposeful representation and categorisation and, hence, facilitate problem-solving.

To illustrate these concepts, consider the following example. The mechanical problem faced by novice motor mechanics will be different from that faced by their more expert counterparts. Expert mechanics will categorise the problem by its means of solution (Sweller, 1989), which is made possible by their possession of a highly developed and organised array of procedural knowledge. The way the problem is represented is central to the categorisation process as it enables the most appropriate solution strategies to be selected. Once a solution path has been selected, the expert actively monitors for anticipated patterns of responses, as the vehicle is being repaired, to validate the initial choice of solution strategy (Eylon & Linn, 1988). If unanticipated events occur during the task, the monitoring informs the expert that the initial diagnosis was incorrect. This leads to further exploration and monitoring and, possibly, a change of strategy. However, the actions of the expert are not guided solely by general problem-solving heuristics; rather they are guided by an interaction among domain-specific propositional knowledge and procedures, conceptual knowledge and higher order procedures (Perkins & Salomon, 1989).

In contrast, novices may not be able to categorise the problem, determine if it is crucial or trivial, choose strategies for its solution or monitor solution progress. These limitations are due in large measure to the kinds of representations available to novices. For instance, they do not have the extensive experience necessary to form culturally sensitive and authentic representations of different kinds of mechanical problems. Nor would they have the experience in solving such problems or knowing when the solution strategies need revision.

Thus, underlying these processes, is the idiosyncratic nature of individuals' representation of problems. These representations are partially dependent upon the observed socio-cultural context, within which motor mechanics work, the artefacts and tools of their practice, and the tasks they have to undertake (Brown, Collins & Duguid, 1989); yet experiences are still interpreted by individuals as products of interactions with cultural practices and artefacts.

Transfer

A criticism advanced against the use of highly specific learning situations is that learning may become bound to that setting eg. learning in informal situations, such as the workplace (Resnick, 1978). However, lack of transfer of learning from one setting to another is an issue for all forms of learning. Research has indicated a lack of transfer between many situations. For example, professional Abacus counters perform poorly when asked to complete paper and pencil maths tests (Stigler, Barclay & Aiello, 1982), and Brazilian street children, with no formal schooling, are able to perform complex calculations as street vendors, yet perform poorly in school-type maths problems (Carraher, Carraher & Schliemann, 1983). Moreover, limits of transfer from formal learning settings, such as schools or vocational education colleges, to other settings has been well documented (Raizen, 1991).

While transfer should and does take place between situations and settings, certain considerations need to be acknowledged. The significance of domain-specific knowledge has been recognised only relatively recently (Glaser, 1984), as has the embedded nature of learning processes (Rogoff & Lave, 1984). Consequently, expectations about sweeping transfer of

knowledge may need to be reconsidered, given these advances. What is important is that transfer within a domain is maximised, and that limits of application be extended by abstracting principles from one learning situation to another (Pea, 1987; Perkins & Salomon, 1989). It follows, then, that concerns about the degree of transfer ascribed to any mode of learning should not be based on whether the setting for that learning is formal or informal. A more useful basis may well be the potential of a setting to generate learning experiences that lead to robust and transferable learning outcomes. Such a requirement is premised on the development of, and interaction between propositional and higher order procedural knowledge (Stevenson, 1991). It is proposed here that socio-culturally authentic learning experiences which drive the learner into activities embedded in the context of their use are generative of procedural knowledge, indexed richly to conceptual understanding, which should facilitate recall, transfer and application.

The next section presents a study of the claims of workers about how they acquire and maintain their skills in informal learning settings — workplaces. The purpose of this investigation was to examine whether the theoretical views discussed above are supported within informal learning situations, in which the participants acquired and developed further their skills. Do these workers report acquiring skills in ways which reflect the constructivist and socio-cultural views outlined above? What lessons are there for the design of learning arrangements from the perceptions of these workers and the literature reviewed above?

Recent studies

Learning in informal settings, such as the workplace, can be dismissed as being ad hoc and peripheral (Resnick, 1987). However, such views are counter to what amounts to common practice within our community. Most apprentices' time is spent learning in the workplace. Surely, the 84% of apprentices time spent learning informally in the workplace cannot be dismissed or discounted? Moreover, the major professions have continued to value the extended periods of workplace practice provided for interns and articled clerks. Surely, these situations are not primarily examples of 'doing time', rather than learning professional skills and attributes?

Two recent studies which surveyed skilled workers' perceptions about the acquisition of their skills produced consistent findings. When skilled workers are asked how they acquired their skills, they frequently state that they have learnt 'through experience', by 'just doing it', 'hands-on', or 'listening and observing' (Billett, 1992, 1993a & 1993b). Skilled workers also report valuing learning in the workplace because of the contributions of that particular learning setting — the guidance of experts and the authentic nature of learning activities. The perceptions of these workers appear to be consonant with the social and cultural basis of the theoretical position outlined above. These two studies are now outlined.

Study 1 — Coal workers

Method

The first study, conducted in the coal mining industry of central Queensland in 1992, used interviews and a survey to elicit responses from coal workers about the nature of their work and the way they acquired work skills. The interviews, which preceded the survey, were conducted on-site with individuals or groups of workers, and were used to determine what sorts of learning arrangements were valued by mine site workers and why they were valued. In order to verify and elaborate on these data, a survey instrument was developed and administered at mine sites which had *not* been the locations for the interviews. The respondents to the survey were first asked *'Describe what it means to be a skilled person in your area of work'*. The responses to this item were categorised into three types of knowledge — propositional, procedural and dispositional (defined below). The respondents were then also asked how they had acquired the skills for the work they were currently doing by nominating among *Integrated on and off job (eg. apprenticeship); College or university-based followed by learning on-the-job; Learning on-the-job; or Another method*. The survey also elicited perceptions about how useful different forms of assistance had been in developing their skills (*eg. External training courses, Other workers on site, Just by doing it*). In addition, the respondents provided perceptions of the effectiveness of aspects of on-the-job learning experiences. These data were analysed by examining perceptions of the contributions of activities that the respondents had engaged in, and how the support they received from

others assisted their learning. Finally, perceptions about the ideal way to acquire their skills for the coal mining industry were elicited. A more detailed description of this study is reported elsewhere (Billett, 1992).

Sample

The sample comprised experienced coal workers. Approximately 75 workers participated in the interviews. These workers comprised a vertical slice of mine site staff. An additional 70 workers from mine sites, different from those where the interviews were conducted, responded to the survey. Although a representative sample of workers was sought, respondents who held supervisory positions were disproportionately represented in the survey instruments which were actually returned.

Findings

Interviews

The interviews, which were used to gauge perceptions of how these workers acquired and developed their skills, provided a number of insights. Respondents emphasised the value of learning in the workplace and learning from other workers while engaged in everyday work activities. It was reported that for skill development processes to be effective they had to be pertinent to the activities, culture and social relations within the mine site. Instructional processes, as well as instructors, that failed to take account of the values and requirements of the setting were likely to be ignored or dismissed by coal workers.

> *'Trainers don't know — have different knowledge'* (coal worker)
>
> *'TAFE out of depth, not relevant'* (coal worker — supervisor)
>
> *'NMEC (national metal's modules) not relevant — '1,2,3,4, hydraulics are no good, they are over-specified , cover the wrong material — these people need to know how to trouble-shoot, not know about the different systems which they are not concerned with'* (coal worker — supervisor)

In only a few situations was expertise external to the mine site valued. For example, the expertise of vendor trainers, whose services accompanied newly-purchased software and equipment, was reported as providing valued insights into how these products functioned.

> *'Vendor training hits the mark — its specific — hands-on..'* (coal worker)
>
> *'..its specialised, teaches you how to trouble shoot and is conducted on-site ....'* (coal worker — supervisor)
>
> *'Vendor training allows you to look at machine when its stopped, allows you to apply prior knowledge — it's practical and applicable'* (coal worker)

However, support for external expertise was qualified. It was not, for example, valued in terms of how the newly purchased equipment could best be utilised at the mine site. In the areas of earth and coal moving equipment, it was claimed that mine site workers knew more about the effective use of the equipment than the manufacturers.

> *'Vendor training for operations is 'no good'.. we know more about it than they do — operations expertise resides on-site'* (coal worker — supervisor)

The interviews disclosed a consistent concern by coal workers about learning arrangements needing to address the context of mine sites. Learning experiences dissociated from mine site activities were not valued.

Survey

(i) Nature of skilled work

The responses to the survey question about the nature of skilled work were categorised into three forms of knowledge: *propositional knowledge* — information, facts, assertions and propositions (Anderson, 1982); *procedural knowledge* — techniques, skills, ability to secure goals; and *dispositional knowledge* — values and attitudes (Prawat, 1989). The categorisation was undertaken by allocating the reported quality to the knowledge type, which was most reflected in the response.

However, this approach has some limitations. Firstly, it is problematic to allocate many of the reported attributes into just one of the categories. For instance, values are influential in the enactment of skills and procedures (Goodnow, 1990). Moreover, some attributes categorised under procedural knowledge include aspects of value and affect. Secondly, some activities classified as dispositional also contain procedural and propositional aspects e.g. 'independent worker', 'team member', 'communicator'. Thirdly, many facets of skilled work are tacit, and not immediately conscious to the skilled worker (Ericsson & Simon, 1984), which may account for the low frequency afforded to propositional knowledge. Nevertheless, despite these limitations, the findings are of considerable interest (see Table 2.1). The strong response to procedural knowledge is perhaps expected, but the perceived value of dispositional knowledge provide interesting insights into perceptions of the nature of skilled work. These coal industry workers perceived that being skilled is more than having useful technical skills. Being skilled also included the ability to use those skills within the mine site, independently and inter-dependently, being able to work with other people and being mindful of the context within which work in coal mining is conducted. Further, the attribute that was most commonly reported was the propositional item of *'understanding about work'*, which was referred to by 38 participants. It is inferred from this response that these workers valued the importance of conceptual understanding about their work.

TABLE 2.1: Frequencies of use of different categories of knowledge (Study 1)

Types of Knowledge	Frequency	(%)
Propositional Knowledge — information, facts, assertions and propositions	42	(18)
Procedural Knowledge — techniques, skills, ability to secure goals	136	(59)
Dispositional Knowledge — values and attitudes	54	(23)

These findings support the need to develop the understanding and procedural ability of skilled workers, and address the dispositional aspects of values and attitudes. However, it needs to be emphasised that these different categories of knowledge do not refer to generic capacities; the

cognitive structures were reported in terms of their being embedded in the context of their application.

(ii) Acquiring skills

The survey responses to perceptions about how these workers had acquired their skills, and what they believed to be the ideal mode of acquisition, provided some verification of what was reported in the interviews. Coal workers who were interviewed suggested that the workplace was the most useful setting to learn within. In Table 2.2, a comparison between the *Method of Acquisition* with perceptions of the *Ideal Method* for acquiring skills illustrates perceptions of work places' utility for learning. It is noteworthy that many respondents, who had acquired their skills through apprenticeship or full-time university/college, claimed workplace learning as the 'ideal' way of acquiring their skills. Although a number of these respondents claimed their initial method of acquisition was the ideal mode, they were in a minority. There was substantial preference for the on-the-job learning by the integrated mode of acquisition group. Moreover, a majority of those respondents, who had acquired their skills in university or college preferred either on-the-job or the integrated approach.

TABLE 2.2: Mode of skill acquisition by ideal method of learning
(Frequencies with % in parenthesis — modes in bold)

Method of acquisition	**Ideal method of acquiring skills**				
	Integrated	Uni/College	On-the-job	Other	Total
Integrated	5	0	**21**	2	28
(n =28)	(7.7)	(0.0)	**(29.2)**	(3.1)	(41.8)
Uni/College	3	**4**	**4**	1	12
(n = 12)	(4.6)	**(6.2)**	**(6.2)**	(1.5)	(17.9)
On-the-Job	2	0	**23**	1	26
(n = 26)	(3.1)	(0.0)	**(35.4)**	(1.5)	(38.8)
Other	0	0	1	0	1
(n = 1)	(0.0)	(0.0)	**(1.5)**	(0.0)	(1.5)
Total	10	4	**49**	4	67
	(14.9)	(6.2)	**(73.1)**	(5.9)	(100.0)

These responses are interesting for two reasons. Firstly, the status of workers, who had acquired skills in the integrated or university/college approach, is linked to their vocational preparation. Consequently, this data provides even stronger support for the efficacy of work place learning, given that the preference is therefore for lower status preparation. Secondly, as these workers engage in activities which are perceived to be highly complex, it may be that these respondents believe that workplace learning has more potential to develop complex vocational skills.

To examine further perceptions of the efficacy of workplace learning, survey respondents were asked to report what they perceived to be effective about this mode of learning. The responses were allocated to one of three categories: those that refer to i) authenticity of activities, ii) the quality of workplace learning activities, and iii) the guidance of others (Table 2.3). The categorisation was based on statements from the survey. Other statements interpreted as having the same meaning, as one already categorised, were aggregated and their frequency reported.

All three kinds of contributions to learning are well supported. The responses to the authenticity of work place activities referred to the reality of tasks which provide contextualised goals and access to models and practice. The quality of work activities stressed variety, autonomy, practice, hands-on experience, self-directed approximations of the task, and engagement with the task. These reported qualities of workplace learning experiences are consonant with those which have been shown to press students, within the practical settings of formal learning settings, into higher order thinking activities (Stevenson, 1986a, 1986b, 1991; Stevenson & McKavanagh, 1991). It is suggested that the quality sought in learning activities is a product of the everyday practice at the mine sites — authentic activities.

However, the contribution most frequently reported was the 'guidance of others'. It was suggested that more experienced others provide both direct and indirect guidance. This guidance was reported in the forms of observation and listening, modelling and joint problem-solving. It was also evident that the contributions of more expert others was accepted and welcomed. Presumably, this facilitates guided appropriation (Rogoff, in print) of the knowledge and understanding required by coal workers.

TABLE 2.3: Coal workers' perceptions of reasons for effectiveness of workplace learning (numbers of respondents in parenthesis)

Authentic activities as learning experiences

'by doing the job you are not just being told how to do the job you are experiencing it first hand' (4), *'things that look 'ideal' on paper or in discussion are more often than not considerably harder to implement in reality'* (2) *'to be able to see at first hand & to practice the given knowledge and skill for operators to perform their work'* (3), *'sometimes its easier to do and learn things by just doing the job at hand'* (3), *frequency of use, practice* (6). (Total 18 respondents)

Quality of workplace learning activities

'variety' (3), *'because of hands on experience'*, (3) *'easier to do the job if you have done it before, — avoid traps for new players'* (3), *'need hands-on experience soon after theoretical for faster learning and less frustration'* (7), *'the best way to do anything in terms of understanding is to do it yourself once you know the right way'* (15), *'experience'* (4) *'self-direction and motivation'* (2), *'once you have spent time on the problem the retention of the solution lasts longer'* (4) and *'learning by mistakes and experience'* (2) (Total 43 respondents)

Guidance of others

'you are learning from someone who knows the practical side of the job, and can answer any questions' (10), *'practice and guidance'* (5) *'watch — pick up a lot by watching; listening — listen to what people say to you, pick up the right way to do things; ask questions — in case you are not sure'* (2), *'if you have two people you have two different approaches to any job, if you are exposed to this you will soon find the best of both worlds and put them to use'* (9) *'by observing other workers enables the recognition of good and bad habits, thus providing the opportunity for the person to achieve'* (3), *'problems are always discussed by the workers and it seems the best way to share experiences and solve problems'* (2) *'you are able to learn a lot from others', 'and not make the same mistake twice'* (6); *'these people are the source of experience and practical knowledge'* (24) (Total 61 respondents)

These data are interpreted as being supportive of learning being an active, constructive and social process, as learners derive meaning from what they experience using direct or indirect guidance of others and expert others. Moreover, respondents in this study suggested that workplaces provide the sort of learning experiences which are effective in pressing learners into high order cognitive activities. It is representations, developed from these sorts of cognitive activities, which are possessed and deployed effectively by vocational experts.

This initial study was conducted within an industry which has a strong and pervasive culture and identity. These factors are likely to be exacerbated by the geographic isolation of coal mine settings and communities. Consequently, the findings of this first study could be challenged, as being peculiar to that industry and workplace culture with a tradition of informal skill development. Nevertheless, the study indicates that, for these workers, workplace learning is perceived as being effective. The responses about the efficacy of the learning arrangements support the theoretical discussion outlined earlier, with learners actively engaged in culturally-derived tasks, being indirectly guided by what they observe and hear, and approximating tasks under direct guidance of expert others. The learners' experiences were situated in a community of practice, being mediated by direct and indirect guidance of others, with tasks and activities being influenced by the broader or distal social or cultural context of the mine site. This initial study prompted a further and broader study to determine whether similar findings would be evident in other industries and occupations.

Study 2 — Workers in other industries

Method

The second study was conducted across a range of industries in Queensland. The study used a survey and interviews of workers with five years or more experience. Data were elicited about the attributes of skilled workers ('skilled' here is taken to include all forms of skilled work, no matter how sub-classified — unskilled, semi-skilled, non-trade, professional), characteristics of skilled work and the ways in which workers had initially acquired, and continued to maintain, their skills. A survey

instrument was developed, trialled, refined and administered in a range of industry settings to groups of skilled workers (see Billett, 1993a).

Instruments

The survey instrument sought to elicit information about the nature of the respondents' work, what it means to be a skilled worker in that type of work, how the skills were acquired to undertake those work activities, the utility of this mode of skill development, how it could be improved, and preferences for the ideal method of acquiring the skills needed to become a skilled worker in those occupational areas.

Procedure

The survey instrument was distributed in a range of industry settings, involving secondary processing, hospitality, retailing and transport work. A supplementary group of forty trades-persons and para-professionals was also surveyed to assist with achieving a more balanced sample. In all, 249 useable responses were coded and analysed.

The interviews aimed to gauge more detailed perceptions about experiences with the methods of skills acquisition and development, across a wide range of occupations. The interviews comprised two sections. The questions used in the first section reflected those in the survey, as detailed above. In the second section, interviewees were asked to think about the last time they had to solve a problem for which they did not have the necessary skills or knowledge. The following questions were then asked.

- *How did you go about learning what you needed to know?*
- *Who or what in the organisation helped?*
- *Did it work?*
- *If so why?*
- *When has this type of learning failed to be useful?*

This procedure was adopted to improve the quality of self-reporting, which has been criticised for a lack of validity (Ericsson & Simon, 1984). By responding to a particular situation, it was thought that the interviewee's

responses would be more likely to be accounts of events, rather than mere opinions.

Samples

The respondents to the survey were classified into one of four common sub-categories of work types — unskilled & semi-skilled, non-trade skilled, trade-workers and professionals. The term 'unskilled and semi-skilled' refers to common classification within workplaces, not their actual required levels of skills or competence. Examples of 'unskilled and semi-skilled' work types included process and production workers and shop assistants. The 'non-trade skilled' category included work types commonly categorised as having a greater degree of autonomy, although not being classified as trade-skilled, for example secretaries, clerks and shop managers. The third category, trade-workers, included electricians, hairdressers and builders. The final category was professional workers, such as doctors, stockbrokers, and engineers.

Interviews of forty-two workers were also conducted. As stated above, the respondents were required to have had at least five years experience in their work areas. However, exceptions were made in some cases where this was not possible. The range of interviewees' occupations was diverse in order to gain insights from different kinds of occupations. The occupations included a stockbroker, forensic scientist, teacher, artist, trades-person, retail worker, clerical worker, store manager, police officer, nurse, union official, warehouse worker and assistant station master.

Findings

Nature of skilled work

The data on the nature of skilled work reported by respondents were again categorised into *propositional knowledge* (Anderson, 1982) — facts, concepts information and assertions; *procedural knowledge* (Anderson, 1982) — techniques, skills ability to secure goals; *dispositional knowledge* (Prawat,1989) — values & attitudes (Table 2.4). Procedural knowledge was most frequently reported, providing 62% of the responses. Dispositional knowledge followed, with this category totalling 30% of the responses; and

propositional knowledge, with 9% of the responses. The low rating of propositional knowledge is of particular interest. Explanations may be that either the respondents did not value conceptual understanding or, perhaps, the tacit nature of propositional knowledge conceals its value from the workers. The high frequency of non-cognitive dispositions, which are often dismissed or ignored within vocational curriculum and learning theory, are again particularly noteworthy.

TABLE 2.4: Knowledge aspects of skilled work
(Frequencies with % in parenthesis)

Types of Knowledge	Frequency	(%)
Propositional Knowledge — information, facts, assertions and propositions	88	(8)
Procedural Knowledge — techniques, skills, ability to secure goals	686	(62)
Dispositional Knowledge — values and attitudes	336	(30)

These perceptions of attributes required for skilled work provide a basis for evaluating the effectiveness of different modes of learning and learning experiences designed to develop these different categories of knowledge. However, the data have some limitations, similar to those in the coal workers' study. Firstly, many of the reported attributes cannot be easily placed in just one of the categories. Secondly, some of the attributes classified as dispositional contain procedural and propositional aspects, for example working without supervision, self-evaluation, skill development, and working as part of a team. Thirdly, as stated above, many facets of skilled work are tacit, and not immediately conscious to the skilled worker (Ericsson & Simon, 1984). This may account for the low frequency afforded to propositional knowledge.

Yet, these limitations do not explain the frequency with which dispositional knowledge is reported in these findings. Dispositions seem not to be addressed adequately within the cognitive literature. Although the roles of perceived self-efficacy and strategic procedural knowledge — knowing how and when to apply knowledge — have been acknowledged within cognitive psychology (Evans, 1991, Gott, 1989), this recognition alone does not

adequately account for all the personal dispositions reported in these two studies. Strategic knowledge is more concerned with the efficacy of securing goals, rather than whether the learner thinks they are worth securing, as Goodnow (1990) has argued. Moreover, values and attitudes are generally marginalised in current vocational education curricula. These dispositions cannot be adequately addressed in pre-specified performance outcomes which form the basis of current governmentally-sponsored initiatives in vocational education (National Training Board, 1992). Moreover, dispositions, values and attitudes are not objective or given; they are generated from individuals' personal history and epistemology, and the community of practice in which they engage (Greeno, 1989).

Perceptions of workplace learning

The interviews provided a variety of perceptions about workplace learning arrangements. The reported contributions of workplace activities to learning were categorised using the same categories as for the coal workers' study: i) authentic of activities; ii) quality of learning activities; and iii) guidance of experienced others (Table 2.5).

i) Authentic activities

The interviews provided perceptions of how authentic work activities contribute to the development of knowledge and understanding. The utilities of actually undertaking work tasks and having to respond to the genuine demands of the work activities, were endorsed as positive learning experiences. The authenticity of the setting was also reported as having pressed learners into situations where they had to solve problems and develop understanding about the nature and quality of work performance. In addition, it was claimed that the authentic experiences provided learning which resulted in outcomes that are robust and aid retention.

TABLE 2.5: Perceptions of reasons for effectiveness of workplace learning

Authenticity of activities	*'learning while you are actually experiencing the job' 'thrown in at the deep end, having to deal with people straight away' 'better grounding' 'because you are there in the actual store where you are faced with day-to-day problems and you learn because it is on-the-spot training', 'We could actually see at the job what is being done to us and we used these skills in each and every day of our working life which is much easier to be taught, especially one on one, than what it was in a classroom', 'I had to do it and it was quicker and I learned by my mistakes', 'you know it's right when it works', 'Learning on the job I tend to retain much more than in the classroom'.*
Quality of learning activities	*'it's much better you can't beat experience' 'the Station Mistress would let you do it yourself. I think I learned a lot more doing that than at the gate school.', 'I think being able to try and do it is a lot better than trying to explain it and you can see what is going on', 'You probably learned better teaching yourself, because its more thorough, rather than skipping over it with someone telling you' when you teach yourself you go more into the workings of why things do what they do, whilst TAFE just teach you the how not why', 'Trial and error has a lot to do with it ... if you make a mistake you will always remember that you have done it wrong — but this is how you fix it', 'I threw the manual away. It only took me about a week of relying on myself before I remembered it. Through the manual I learned how to do things but I did not actually remember'*
Guidance of experienced others	Access to experts — *'you had them there everyday'* — *they monitored progress and counselled to avoid bad practice'*. Learning on-the-job from people who were more experienced — motivation and initiative emphasised. Observation and consultation with peers — *'you see how other people deal with difficult customers, follow your example', 'Seeing what action other people have taken provides guidance on which way you should go or what action you should take', 'Not taken apart from other workers. You are with the other workers who are doing the same thing so you can watch them', 'What was useful is that most of the people work the same way within the office so how you are taught here really related to how everyone else works and how everyone else does their job in this company'*

ii) Quality of learning activities

As reported in the previous study, the active and engaging nature of workplace learning was emphasised by the interviewees. Phrases, such as 'doing', 'trial and error' and 'being able to try', connote a form of learning which is active and engaging. Moreover, the value of learning autonomously was also reported as being highly engaging and demanding in developing understanding. It is postulated that these type of activities press learners into higher order thinking and place them in a highly active role, not only in initiation of the task, but also in the monitoring and self-regulation of task performance (Stevenson, 1986a, 1986b, 1991). This approach to instruction, as long as the tasks are within the learners' Zone of Proximal Development — that is where they are able to achieve with some guidance — could assist with development of the array of procedures required of experts.

iii) Guidance of others

A number of interviewees suggested that access to, and guidance of experts and other workers was of great utility in their learning. It was reported that on-going everyday guidance provided a form of support which permitted monitoring of an indirect nature. Also, the actions of both more and less experienced peers, permit a form of modelling, as novices compare their performance with those around them. The culture of work practice is also evident in the daily activities of the workplace which provides norms and exemplars for appropriation of work practice (Lave, 1990).

Limitations of workplace learning

As with the first study, some respondents in both the survey and the interviews, were critical of workplace learning arrangements. The areas of concern were about maximising benefits from guidance of expert others and the structuring of learning experiences. Concerns about the guidance of other workers were associated with availability, access and willingness of mentors to provide guidance and support (Table 2.6). In addition, it was suggested that some form of structure be provided to remove 'adhockery' of learning experiences. This need accords with that of Lave and Wenger (1991) that, in seeking coherence of learning experiences, it is necessary to

move the novice from the periphery of practice to full participation. This involves providing opportunities for the novice to become competent in peripheral tasks and to move through the increasingly complex tasks of the community of practice. Finally, concerns about being unable to access the range of guidance and support were made by learners, who had experienced isolation. Responses to the question about ways of improving workplace learning, included suggestions about more time with 'expert others', more time in the learning process, maintaining currency of trainers' knowledge and the need for structure in workplace learning programs.

TABLE 2.6: Suggestions for improving workplace learning

Problems

- access to expert staff
- being given sufficient guidance or tutoring. There are limits to what you can achieve with initiative — guidance is required.

  'it depends who you are working with' 'not knowing. No support, guidelines. It has just been a process of trial and error.' 'Learning on-the-job in isolation just takes a long time'

- more time to learn on-the-job with guidance and support
- reluctance to ask questions of people in workplace

Suggestions for improving this method (frequency in parenthesis)

- additional time with experts (16)
- more time in the learning process (24)
- currency of trainers' knowledge (9)
- structuring or formalisation of the provision(11)
- group sharing of ideas (7)
- texts to support on-the-job learning (5)
- availability of specialist or specific courses (13).

One of the clearest outcomes of the second study was strong support for learning through engagement in authentic occupational activities, supported by the direct and indirect guidance of others, and the active nature of authentic work tasks. Although these activities are not always intended as learning activities, they were reported as engaging the learner in thinking processes that are analogous to those reported as pressing students into higher order thinking in TAFE settings (Stevenson and McKavanagh, 1991). The guidance provided by expert others, in both direct and indirect ways, together with the work activities, allowed learners to observe, conceptualise and attempt increasingly mature approximations of tasks.

Notably, respondents with problems of access to these types of learning arrangements, such as those who are physically isolated in some way, referred to the frustration and slowness of learning without expert support. Some of these latter respondents reported having developed strategies to access support. Moreover, these learners did not want just any support, they wanted assistance by experts who could provide access to information that was otherwise inaccessible.

However, it should be noted that a number of skilled respondents did emphasise the need to develop theoretical knowledge and understanding, and expressed concern about the ability of workplace learning to provide this knowledge adequately.

Implications for the development of vocational expertise

The theoretical discussion in the early sections of this chapter has focussed on the way knowledge is constructed by individuals. It has been argued that this construction is mediated by the social and physical context of the application of the knowledge. It has also been postulated that this process leads to the appropriation of socially-derived norms and practices of occupational activities. However, it has also been argued that the nature of appropriation is problematic. Individuals do not simply 'internalise' externally-generated knowledge, but seek viability with existing socio-culturally derived knowledge and understanding. Such a view of learning

has consequences for the development of expertise in both formal and informal learning settings. In this section, these implications are discussed.

Three general implications flow from the discussions and studies above. Firstly, the development of knowledge for vocational practice needs to be conceptualised as a learning process, rather than a teaching process. Knowledge and understanding are not wholly transferable from one person to another, and communication is not a simple means of conveyance (von Glasersfeld, 1987:11). Secondly, learning processes need to be embedded in the socio-cultural context in which knowledge will be appropriated. This embeddedness allows learners to extend their current understanding through experiences that will make the understanding coherent and applicable to vocational activity. Thirdly, the ability to transfer knowledge is dependent on the development of self-management and regulation skills or higher-order procedural knowledge.

These implications apply also in situations where learning is described as spectacular and transfer common. This occurs when learning takes place in context, is effectively mediated and is functional (Bransford et. al., cited in Pea, 1987). For instance, children in their first five years gain a range of technical and social skills with limited obvious effort. These learners receive immediate feedback on their efforts, while more expert others serve as models for imitative learning and provide structure and connections for learning. In addition, the functional nature of the learning activities assists in understanding the function of information for problem-solving, as it is made explicit to the learner (Pea, 1987:651).

As a way of conceptualising findings from the discussions and studies outlined above and determining implications for practice, it is useful to consider the learning process in terms of activities and guidance. These categories refers to the activities that learners engage in, the guidance of others (industry experts) and the effects of the social and physical context in which that learning takes place.

Activities

It has been argued that learning experiences, which include activities that are socially and culturally authentic, generate viable outcomes.

Underpinning the concern for authenticity is the belief that activity structures cognition (Rogoff & Lave, 1984; Scribner, 1985). Consequently, the quality of learners' experiences and the way those experiences are accessed are key factors for learning outcomes. Learning experiences or activities need to stress authenticity in order to be generative of viable knowledge. In the workplace authentic activities are provided gratuitously. However, some structuring and explicit mediation may be required to ensure that learners are provided with a sufficient range of activities to allow development of the complex understanding required for work activities.

The provision of authentic experiences, for learners in formal learning settings, may assist with development of viable understanding. TAFE colleges have attempted to provide authenticity with real-world exercises, simulations and facilities, such as training restaurants and hairdressing salons. Yet these learning experiences, while being useful, remain substitute. Learners are conscious of whether they are working in an authentic restaurant or a training restaurant. Learners are aware that they are students, and the quality of the proximal elements of guidance, observation and demonstration being undertaken are between themselves and their teacher or other students. Learners are also mindful that the activities they engage in are educational, with outcomes, expectations and demands being associated with formal instruction, assessment and certification. Consequently, learners' efforts are focussed on meeting the demands of the formal learning settings, not the requirements of work skills (Billett, 1993b).

Concerns with substitute contexts include the view that it is not sufficient to teach knowledge and procedures in isolation. Learning processes must also focus on conditions of application of the knowledge and skills to be learnt (Brown, Collins & Duguid, 1989). The problems facing learners are embedded in a particular context. Moreover, the solutions to the problem are equally embedded in that context (Scribner, 1985). Hence, curricula for formal setting needs to provide adequate experience with authentic problems and problem-resolving activities. Equally, the nature of work activities makes learning experiences highly active. As stated above, those sorts of activity that allow learners to initiate, trial, monitor and evaluate the effectiveness of approximations of tasks are those that are conducive of

developing higher order thinking skills (Stevenson, 1986a, 1986b, 1991; Stevenson & McKavanagh, 1991).

Guidance from others, experts and the social and physical context

A view which suggests learning is a matter of construction, rather than instruction, poses significant questions about the roles of teachers and trainers. Recent innovations and approaches to instruction such as Reciprocal Teaching of Comprehension (Palinscar & Brown, 1984), Cognitive Apprenticeship (Collins, et al, 1989), Apprenticeships Instruction for the Real-World Tasks (Gott, 1989), Apprenticeships in Thinking (Rogoff, 1990), Legitimate Peripheral Participation (Lave & Wenger, 1991), and Guided Participation (Rogoff, in press), all emphasise a social basis for the construction of knowledge and imply the need to place learners in a role which presses them into taking responsibility for constructing meaning and reordering this meaning within a community of practice.

Consequently, the vocational instructor's role becomes one of organising experiences that allow learners to develop their knowledge and understanding, through a process of experience, conceptualisation and refinement (von Glasersfeld, 1987). Such a view extends the concept of teaching practice as making sure the learners are doing the thinking, to one of making sure their thinking is guided towards the effective organisation of viable knowledge. This change in emphasis of the instructional role is exemplified by von Glasersfeld's notion of reinforcement. He suggests that instead of reinforcement being equated to external statements of endorsement or rewards by teachers or experts, it needs to be equated to the learner achieving a satisfactory organisation of knowledge, a viable way of dealing with some sector of experience, and the rewarding consequences of a fit being found within the individual's own system (von Glasersfeld, 1987:15). This does not negate the value of extrinsic rewards, such as verbal reinforcement, but suggests that this is secondary to the inherent rewards that learners enjoy in extending their viable knowledge base.

Teachers in formal learning settings might also consider ways of guiding learners through experiences that facilitate the construction of meaning. Yet, such instructors have the problem of either transforming, or being

constrained by, a substitute context. Conversely, informal settings, such as the workplace, appear to be well placed to provide experiences that are generative of a rich construction of knowledge through engagement in a community of practice; yet they too have problems with making explicit that which is tacit or hidden. Cross-cultural studies have found that, while much learning is undertaken as part of everyday activities, explicit instruction is very much a part of situated learning. For example, Pelissier (1991) reports that learning navigation in Palawat includes direct instruction, with substitute artefacts, such as stones and shells, being used to represent star patterns.

Activities and tasks are central to considerations about the development of robust representations and understanding (Posner, 1982). However, the organisation of experiences is more than setting tasks. What is set for learners may not be what they engage in. The task, set as a problem-solving activity, may well turn out to be a trial and error activity (Posner, 1982). However, guidance from teachers, trainers or content experts can include a focussing of learners onto the purpose of the activity. For example, learners may not be able to address a new situation. This might be because they cannot see the linkages between what they know and how they are representing the new situation. Access to existing knowledge and linkages to the new task can be made through explicitly making the connections (Pea, 1987) and using good examples, analogies, models, and metaphors (Posner, 1982). In these ways, teachers act as guides in the learner's Zone of Proximal Development, with experiences and guidance making viable, and extending, learners' understanding.

The approach suggested within cognitive apprenticeship of modelling, coaching, scaffolding and fading (Collins, et al, 1989) is a strategy which aims to develop expertise, whether in formal or informal settings. In this approach the instructor models the activity, and then provides support for learners to achieve successful performance, through progressively mature approximation of the expert-modelled task. Similarly, the reciprocal method of learning (Palinscar & Brown, 1984) is also an approach which seeks to make explicit the thinking processes of experts. This latter method, along with the modelling, coaching and scaffolding of cognitive apprenticeships, aims to develop the self-monitoring and self-correcting skills possessed by experts.

However, as reported above, because of concerns about generating sufficient conceptual understanding in workplace learning, interventions designed for the formal learning setting may still be needed in informal settings. At the same time, the need to instruct explicitly may be more a challenge in formal learning settings which lack the indirect guidance experienced in authentic settings. Observation of product and process, availability of visual clues and social contact with a range of experts, which are all usually part of workplace experiences, may need to be provided for in other, and more explicit ways, in the formal setting.

Although the indirect effects of the physical context are not always apparent, they can be pervasive. During an interview in the second study reported above, a warehouse worker commented that if he was ever in doubt about how to pack boxes onto a pallet he had only to look around the warehouse to see a library of approaches to this task (Billett, 1993b). Equally, other workers (eg. motor mechanics) will be reminded of previous problem-solving activities as they observe the engine they are working on and its responses to their procedures. These physical clues are particularly important for novices because, until rich representations have been developed, they are more reliant on indexing the physical context. This development of structural representations involves moving from context-dependent thinking to context-independent thinking (Prawat, 1989:20), a quality possessed by experts. Formal learning settings may not always provide the appropriate indexing. Thus as argued elsewhere (Billett, 1993b), learners whose only experience of vocational activities is provided by the substitute environment of formal learning settings may develop conceptualisation and representations which are dysfunctional in terms of application of vocational skills in the workplace. Consequently, early access to authentic settings of vocational practice is recommended, to achieve the development of conceptual understanding based on the authentic context of the vocational setting, rather than the substitute context of the formal learning setting.

Conclusions

The studies reported in this chapter provided consistent findings. The frequencies with which different categories of knowledge are reported as being required by workers across a range of different types of work were

broadly consistent. In addition, the nature of learning experiences provided in the workplace were reported as being consistent. Also, the participants' responses provided broad support for the theoretical position advanced in this chapter.

When workers in both studies were asked to state the characteristics of skilled workers, they provided consistent responses in the reporting of the attributes required for skilled work. Procedural knowledge, was most frequently reported (59%, 62%), followed by propositional knowledge (18%, 8%). It is suggested that, as propositional knowledge is often tacit, its value may be concealed from the respondents. The frequent reporting of attributes, that were categorised as being largely dispositional, (23%, 30%) is of considerable interest. It is inferred from both studies that the values and attitudes which underpin skilled performance are crucial. Yet dispositional knowledge is largely ignored in vocational education curriculum. Moreover, current governmental initiatives, in vocational curricula, which conceptualise vocational activities as pre-specified outcomes are unlikely to emphasise this type of knowledge sufficiently. In addition, this type of knowledge is not sufficiently emphasised within cognitive learning theory.

The studies also produced consistent suggestions for improving workplace learning experiences by giving attention to the authenticity of learning activities, quality of learning activities and guidance of others. In both studies it was perceived that authenticity in workplace learning was of considerable utility. It was suggested that engaging in legitimate tasks, being able to observe both the process being undertaken and the product, and having access to extensive practice provided a good basis for effective completion of work tasks. Workplace learning experiences were preferred when activities were active, varied, autonomous and encouraged the learner to be self-initiating and monitoring. It is argued that the self-directed nature of these learning experiences are likely to secure higher procedural knowledge, as learners are pressed into developing and utilising different categories of knowledge required to respond to legitimate problems.

The data broadly support the theoretical propositions developed earlier in the chapter where learning is perceived as an active process, in which the individual takes the primary role, but where the mediation of others (including expert others) contributes to the development of knowledge. It

was evident that learners could proceed without others to guide them; however, the direct and indirect guidance of others was highly valued. This guidance provided access to heuristics, or 'tricks of the trade', which helps workers secure goals. In addition, guidance was reported to permit observation and access to discourse which resulted in developing understanding about the nature of tasks and products. Equally, this guidance in an authentic setting provided access to the dispositions which characterise skilled workplace performance.

However, limitations of this data need to be acknowledged. The data are based on self-reporting, which may fail to address the tacit nature of aspects of expert action. The data are these workers' perceptions and may not accord with those of others.

The studies reported above are supportive of workplace learning. However, generalisations from these findings should be cautioned. Firstly, learning is not benign. The degree to which any learner will engage in, and benefit from, workplace experiences is effected by their personal history and dispositions. Secondly, in aggregating the experiences of a large sample of workers, it is necessary to note that the reality for individual learners might be something quite different. Learning experiences, in many workplaces, may lack expert guidance and engage learners only in peripheral activities. However, the result might be the appropriation of unsatisfactory learning outcomes. Thirdly, whereas the workplace is reported as providing, gratuitously, experiences that are conducive to the development of procedural and factual knowledge, the development of conceptual knowledge may require explicit instructional intervention.

To conclude, this chapter has advanced an approach to learning which draws upon current theorising and finds support within recent research. Its primary aim has been to develop understanding of the effects of informal learning settings, in order to conceptualise the construction of knowledge for the development of vocational expertise. It is proposed that judgements about the value of learning settings should not be made on the basis of their being either formal or informal. Rather, their capacity to provide learners with experiences that are conducive to developing the bases of knowledge structures and dispositions needed in vocational practice, should be the basis of judgements about worth. The workplace provides a range of

authentic conditions for the development of vocational skills and these should be garnered.

The concepts of learning examined in this chapter also pose questions about the efficacy of instructional practice in formal learning settings, such as TAFE colleges. While these conclusions might seem to be critical of such formal earning settings, this is not the intention. Rather, it is suggested that if the situated nature of learning, is ignored, education may defeat its own goals of providing useful and robust knowledge (Brown, et al, 1989).

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3 Learning in apprenticeship courses

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Abstract *The adoption of competency based approaches to apprenticeship and other training programs in industry and TAFE in Australia raises some important issues. These include the nature of competency, the curriculum as a progression of knowledge and skill, and ways of encouraging learning. This paper explores these issues with relation to learning in welding and electrical installation, as examples of trade skills. A method for developing expert models is described and illustrated as an approach to understanding competence as including both conceptual and perceptual knowledge as well as performance. The use of such models in deriving curricula is then discussed. Some features of instructor-apprentice interaction in workshop settings that may encourage deeper learning are presented and preliminary experimental results in the two trade areas reported.*

Introduction

The adoption by TAFE and Industry of competency-based approaches to apprentice training and education brings to focus a number of important questions which have long been issues. These include: (1) the nature of competency; (2) the curriculum as a progression of knowledge and skill; and (3) processes of encouraging learning. In this chapter, these issues are discussed with particular reference to skill learning of apprentices in welding and electrical installation, as two examples of trade based vocational learning. Much of the discussion is general and applies to skill learning in many vocations, including both trades and professions. However, these general points take on a particular cast in different areas and are therefore illustrated with research in two specific areas. A fourth critical issue is that of assessment. Discussion of this, however, is restricted to its role in the other three issues.

Much of the emphasis so far in the adoption of competency based approaches in electrical trades and metal fabrication has been placed on

standards of performance and assessment and on the production of modules. There are progressions of tasks from earlier to later modules, with some background information and principles. There has been less emphasis on the definition of criteria and standards in assessment which might be applied to this progression, while a conceptual analysis of expert skills has not really been made. There has thus been little attention to the cognitive underpinning, conceptual or perceptual, of different skills, to the learning processes used by the apprentices, or to the role of the teacher in promoting optimal learning processes and developing learning contexts in such a way that students can maximise their learning.

In these early stages of using competency based approaches, when there is the opportunity to revise materials and to shape the system of delivery, it seems essential to consider these important issues. No definitions of desired performance standards can be of much benefit if learning tasks and learning processes do not allow them to be achieved efficiently, or if the underlying knowledge of expert performers is not well understood.

The nature of competence

The terms 'competency' and 'competence' are often used interchangeably in the literature, but it may be useful to use the different terms to refer to somewhat different ideas. 'Competency' is most often associated with a purely *performance* approach to skill and its assessment, i.e. being able to perform a task to a particular standard on a particular occasion, in a particular situation, with particular materials and equipment, and to a particular specification. There are inherent dangers in using such assessments in accreditation or in guiding curricula, particularly in a one off test. They do not take into account the way the person *controls* the performance so that standards can be maintained, and improved, over different times and situations, and with different materials, equipment or specifications. It is the knowledge and skill with which the person exercises such control that is here referred to as 'competence' (Evans, 1992).

Our research team has recently attempted to use interviews and card sorting tasks to obtain a first approximation to expert competence in manual metal arc welding (MMAW) and in electrical installation (Evans and Butler, 1992, 1993). In the case of welding, we held informal discussions with and

made observations of nine college welding teachers and six industry welders on the process of welding. From their information on the processes they used, we placed the terms they mentioned on a set of cards, one term or phrase per card. Two welding teachers initially undertook to sort the cards, in order and category of process, rejecting terms referring to processes or ideas they would not use and adding alternative and extra terms. In this way, by working with more teachers, we gradually built an increasingly more sophisticated *knowledge map* or *concept map* of expert processes (Evans and Dansereau, 1991). In each case the teachers began with the unsorted cards, but their concept maps converged to ones with two common features. First, the teachers sorted the cards into four sections, in the following order: preparation, manipulation, indicators, and features of the final weld. Second, in spite of some differences in terminology, the allocation of the cards to these sections was almost identical, as were their explanation of the processes.

The next part of the procedure was to use the card sorts and explanations to develop a concept map with the links between sections, or phases, included. These links involved: (a) the flow of events, (b) expectations of physical causation (PC), and (c) information processing (IP) on the part of the welder. The version of the concept map we now use as a working model is shown in Figure 3.1.

Some important features of this expert model include: (a) the cognitive aspects which control the successive phases; (b) the understanding or expectation that the characteristics of welding events will inevitably result in particular weld outcomes; (c) the ability to examine the weld product for faults, either based on appearance, or where possible by breaking (destroying) the weld to examine its internal structure. This last observation is of course only available in 'trial' welds. The events of welding include preparation of materials and selection of electrode and settings, manipulations during welding, such as adjusting the arc gap, angle, or speed of the electrode, and indicators that can be seen, heard, or felt.

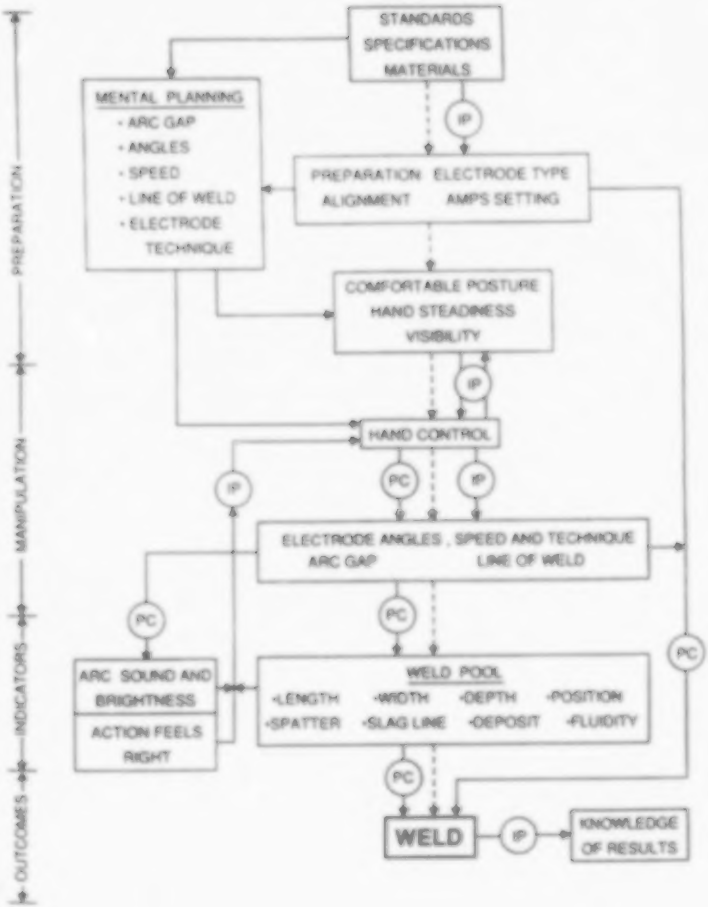

FIGURE 3.1: Expert model of manual metal arc welding

(Based on Evans and Butler, 1992)

Two important features of this expert model are not dealt with explicitly by the welding modules, nor, in our studies, by many teachers. First, there is little mention of the 'indicators', that is the task feedback available to the welder from the task events as he or she actually does the job. Yet this perceptual feedback is at the heart of the way in which the welding actions are regulated. Through such indicators as the characteristics of the molten pool of metal (weld pool) which, on solidifying, forms the weld, the appearance of molten slag, the sound and brightness of the electric spark or *arc* between the welding rod and the plates of metal to be welded, and the position of weld pool, the welder regulates actions to maintain the standard required, and can *prevent*, or failing that, *anticipate* any defects in the finished product. Including progressive reference to this perceptual information would seem at least a useful candidate for the design of the modules. It is true that, by Stage III, according to our studies most apprentices are able to tell how they use *some* of these indicators. What is in question is whether this knowledge is best learnt, as at present, mainly by dint of practice, or whether the teacher or industry trainer can draw the nature and use of indicators to apprentices' attention, progressively, and explain them more precisely.

The second feature relates to physical causality. For example, the preparation of the metal plates by grinding the surfaces to be welded and setting alignments alters the weld outcome. *How* to do this preparation is certainly mentioned. Less emphasised is *why* such relationships exist, in terms of the properties of the metals, e.g. steel or aluminium, or in terms of heat transfer and stress. While such concepts are present in the 'theory' aspects of the course, they are not necessarily part of the conversations between teachers and apprentices on the workshop floor.

The 'expert model' thus serves to highlight those aspects of the curriculum or of teaching which deserve further consideration and research. How such teaching and research can be done is discussed below. The model of Figure 3.1 is far from complete. A number of features require extra research, including: (a) adjustments for different welding applications, both within MMAW and across different welding processes and different metals; (b) more specific descriptions of the indicators; and (c) a better indication of conceptual knowledge involved in learning to weld and actually welding. Some of the features of the indicators and the concepts involved may well

be at the level of 'unconscious' use by experts. It remains important to pursue them.

The expert model for domestic electrical installation was produced in a similar fashion to that for welding (Evans and Butler, 1993) by interviewing electricians and teachers of electrical installation. It, also, acted as a way of helping both researchers and teachers to understand the expert process to which various modules are intended to contribute. As with welding, the main phases identified were planning (preparation), installing (manipulators), and testing of outcomes.

In the case of domestic installation the use of indicators was present in a different way from welding. While there are clearly task feedback aspects of physical manipulations such as terminating conductors or attaching electrical fittings, such manipulations are considerably simpler than those involved in welding. There is another type of monitoring, however, somewhat different for each of the phases, that depends more on the electrician's understanding of the task. Such 'monitors' include checking observance of AS3000 rules and efficiency at each phase, cost, at the planning stage, and neatness, safety, and adherence to the wiring plan at the other phases. Such monitoring features appear to be continually present, even when the electrician is operating routinely. Again, what needs to be further researched is what role electrical principles play in the expert performance.

The curriculum : progression from novice to expert

Descriptive approaches

In the burgeoning literature on the progression from novice to expert in many fields, much research has been concerned with descriptions of the differences between the two. While this research has been helpful, it does not address the important question of how competence progresses (Campbell, Brown and DiBello, 1992). In order to do this, two approaches

seem useful, the one emphasising general development or progression, the other focussing on the cognitive processes by which development occurs.

One of the best known attempts at describing progression in the development of competence was that of Dreyfus (1982), whose description for business management has been applied in other fields, for example, nursing (e.g. Benner, 1984) and teaching (Berliner, 1988). Dreyfus postulated five stages, which may span many years in their development. For example, Stage 1, *novice*, characterised by limited, inflexible, rule-governed behaviour, is typically begun by teaching simple objective attributes of the environment which may be manipulated by simple rules, but without sensitivity to situational conditions. At Stage 2, *advanced beginner*, in addition to the set of rules, the person learns many of the important situational aspects of the task, although he or she may still have difficulty in recognising which features are most important. Stage 3, *competent*, which Dreyfus, in his work, saw as occurring after two or three years, develops when the person sees actions in terms of goals and plans, which he or she develops after considerable thought and selection of *important* features of the situation, and which are consciously used to guide action. Stage 4, *proficient*, follows considerable experience, so that the person is able to select, seemingly unconsciously, the best plan to follow for a particular situation from a very large repertoire of possible plans. Situations are summed up quickly and plans are quickly selected or adapted. At stage 4, actions are still, according to Dreyfus, governed by rational or deliberative cognitive processes. However at stage 5, the *expert* level, the performer, acting *apparently intuitively* from a deep understanding of the whole situation, appears to be no longer aware of the features and rules, and his or her performance becomes fluid and flexible and highly proficient.

The first important point that follows from this analysis is that the performance of the expert may give few clues as to the course of development. The expert differs profoundly from the novice in being able to perceive situational features, in selecting which of these features are important, in being able to apprehend the situation *as a whole*, rather than analyse individual features, in the sheer number of available plans and remembered instances, and in making appropriate decisions intuitively rather than through deliberate problem solving. It would certainly seem

difficult, if not unwise, in any substantial skill, to attempt to teach expert behaviour directly to a novice.

Once it has been pointed out, this or a similar progression can be readily recognised in many areas of competence, including skill in welding and electrical installation. This leads to the second point. This progression represents the *status quo*, that is, the result of skill teaching environments and curricula which have not necessarily developed optimal procedures. For this reason it seems useful to describe a more *specific* list of developmental continua for various skills. In the areas of welding and electrical installation, some possible directions of change are listed below. Most of these have not been researched specifically for the learning of trade skills, but they point to more specific foci to examine.

Domain specific questions

1. **Change from perception of isolated features to perception of covarying relations.**

To take an example in the case of welding, 'tacking' the plates to be welded in such a way as to allow correct penetration and final alignment in the finished job has effects in what can be perceived during welding as well as in the outcome. Novices are likely to see these features of preparation and in-task indicators, separated as they are both in time and in the manual and cognitive processes involved, as isolated events. Similarly it takes time for learners to be able to perceive the weld in progress as a set of coordinated features and actions rather than particular isolated features. The empirical question is whether teaching aimed at the understanding of the perceptions and relationships pays off in faster acquisition of expertise for the apprentice, as assessed by his or her meeting specified standards on various criteria.

2. **Changes in the perceived utility of conceptual knowledge.**

According to the Dreyfus account, conceptual knowledge is not consciously entertained in experts' practice unless the person encounters an unexpected

difficulty. This is also the conclusion arrived at by Anderson (1982, 1990) in his analysis of the learning of geometry and computer programming. However, other evidence (e.g. Taylor and Evans, 1985) suggests that conceptual knowledge appears to drive the acquisition of some cognitive skills and could be available continuously even in expert performance. It seems that in many tasks, people may benefit from the use of a mental model of the device or system (e.g. Schumaker and Czerwinski, 1992). In the case of electrical studies, our present work suggests that understanding why circuits behave as they do may help students become more able both to test for faults and to locate the fault, once detected. Electricians undertaking advanced diagnostic tasks, e.g. seeking for faults in a generating plant, have reported to us that they have a cognitive map of the different circuit components and of the current flow. Expert welders have described to us how they think about the heat transfer in the metal as they are doing precision work. How important it is to *integrate* conceptual knowledge with practical performance, *from the beginning*, has not yet been addressed in competency-based approaches.

3. Increased proceduralisation.

One of the obvious aspects of increasing expertise is greater automaticity in using critical procedures. The pay off for this automaticity is that attention is freed to focus on other aspects (e.g. Anderson, 1990). We have attempted experimentally to demonstrate this in our own work by asking participants to perform a simple secondary task while they were welding. The task was to say 'now' when they heard a high pitched sound, occurring at random intervals, in earphones they were wearing. We also recorded any decrease in weld standard at the time of sound. The results have not yet been fully analysed, but they suggest that, as expected, beginning welders have a much longer delay in responding than do experienced welders, suggesting that they need to concentrate much more of their attentional resources on the task.

Increasing procedural skill is also accompanied by increased attention to features of welding other than manipulation. We questioned 11 Stage III apprentices and 8 Stage I apprentices on causes of defects in welds they had just completed and how they would prevent the defect next time. Of the Stage I apprentices, 78% thought the cause was in their manipulators (i.e.

procedures. See Figure 3.1), contrasted with 22% for preparation. For the Stage III apprentices, the causes given were 50% for each. For the prevention of faults, the differences were even greater. In Stage I, 67% mentioned manipulators and only 8% preparation; in Stage III, 23% mentioned manipulators and 55% preparation. To a large extent, these differential results may be attributed to emphases in the curriculum at each stage. What needs to be considered is the effect on overall performance of encouraging learners to develop one aspect ahead of others.

4. Changes in ability to diagnose faults.

Two types of problem solving have been identified. One has been described as *backward reasoning* or the use of 'weak' methods (e.g. Anderson, 1990; Patel and Groen, 1991). One common approach is for the person first to identify what the problem is and then to set up alternative hypotheses from the available cues. These alternative hypotheses are then tested by gathering appropriate data, leading finally to a solution. The process is 'backward' in that the hypotheses largely precede the data gathering.

Such *general* approaches to problem solving have often been explicitly taught. Because these approaches were often researched with 'knowledge-lean' tasks (Glaser, 1984), they do not take into account the additional conceptual and procedural knowledge available in specific fields. What is involved in expertise is often *forward reasoning*, using 'strong' methods, where, starting with salient features of the problem, the person works out, from domain specific knowledge, the conditions that might have caused them, and those conditions which may be ruled out, and so on to a few testable hypotheses, or even only one. A typical problem for an apprentice in a welding task is to recognise faults and to work out how to avoid them, or, for an electrician, to detect and diagnose faults. While there are general thinking skills involved in this, what is principally involved is the use of domain specific relationships, for example, in welding, between aspects of preparation, manipulations, indicators, and outcomes. Learning these relationships may be critical to improvement. How to learn then is an important question.

While these four aspects of increasing competence may not be incompatible with the progressions in the Dreyfus model, they suggest questions about

how teaching and well thought out learning experiences may influence these progressions, rather than simply letting nature take its course. Through improvement in teaching it may be possible to shorten at least the early phases of the development of expertise.

Procedures-based and concept-based skill learning

The above discussion has referred to the role of understanding concepts in the learning of procedures. A useful distinction is between approaches to curriculum for apprentices that rely on the learning of procedures only and those that incorporate an understanding of the concepts involved and of how the particular devices and methods used actually function. One extensive review of both of these approaches, applied to the learning of computer programming and to trouble shooting with electronic devices, was carried out by Gott (1988). Gott's review showed evidence of the superiority of the second approach, involving conceptual knowledge. While different domains are certainly unique in their requirements, it is useful to set out in general terms what might be involved in a concept-based approach. The model is useful because it draws attention to the need for progressive goals, reflection, and understanding in skill learning.

In practical domains, according to Gott's analysis, experts are capable of engaging in reasoning that involves the coordination of three major sources of knowledge or skill: procedural (how-to do-it), propositional or declarative (understanding of the system or device), and strategic (how-to-decide-what-to-do-when). Also, skill acquisition occurs through successive approximations to the targeted expertise. The progression is characterised by movement in these three aspects from partial to more complete.

Applying this analysis to trade teaching results in the following sequence. There is first an analysis by the teacher of expert procedures, resulting in statements of the expert procedure and underlying concepts. These statements (or diagrams, etc.) are *simplified* into initial instructional statements by the teacher which the apprentice must comprehend and operationalise into a first attempt at the procedure, with the help of problem solving strategies. Success at this point is followed by reflection on the part of the apprentice and by more complex instructional statements on the part of the teacher, which more closely approximate the teacher's knowledge.

These are interpreted by the apprentice into a more advanced form of the procedure and strategies of use, and so on. As the learner develops more complete understanding and skill, he or she is also involved in goal setting, planning, implementing, monitoring, and evaluating, and is informed by increasing understanding of the system involved. Each step in procedural or skill knowledge is also enhanced by practice itself.

Again there is a need to develop procedures for implementing this kind of progression in curriculum and teaching. This implementation may be done through a formal, developed curriculum, which the teacher and learners follow. The National Modules, for example, could be written in this way. The essence of the approach could also be incorporated into teaching procedures, where its application could be more flexible, and where the next step in the progression is dependent on the particular student's handling of the task at hand. This type of flexible approach may well be suited to normal workshop classes and industry training. An approach that uses some of these aspects is described below.

Learning and using within-task feedback

The examples of expert models in welding and electrical installation discussed earlier both incorporated the notion of task-feedback, or indicators, use of which appears to be an important, if not a central, aspect of expert performance. It is useful to consider this aspect more fully as part of the progression from novice to expert. What is task feedback and how is it learnt?

While it was developed with restricted motor tasks carried out in laboratory conditions, a useful model for understanding task feedback can be extrapolated from the theory proposed by Schmidt (1975). In Figure 3.2, this model has been adapted and simplified to fit welding performance particularly. It is presented here as a means of arguing for the possible utility of 'indicators' or 'monitors' in curriculum development, rather than a empirically justified model.

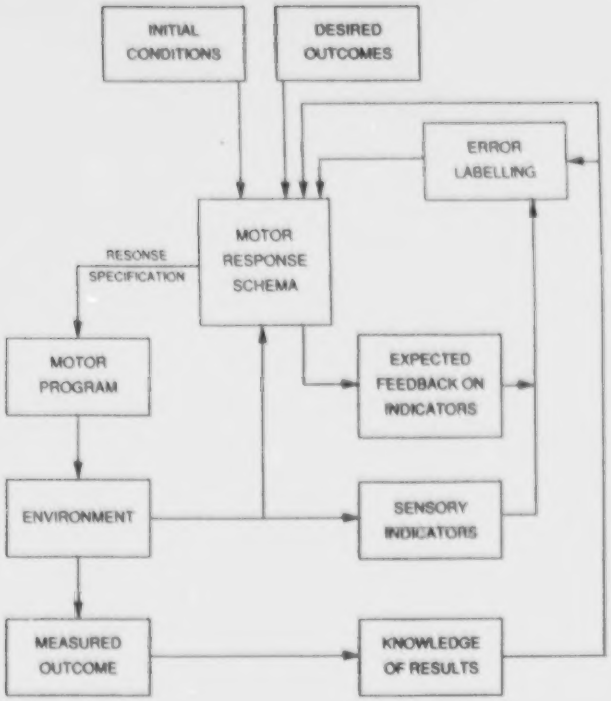

FIGURE 3.2: Flow diagram showing possible elements in welding performance

(Adapted from Schmidt, 1975)

In Schmidt's theory, the model centres around the notion of a general motor response schema, such as might be used in hand-writing or manual metal arc welding. This schema, or constellation of potential motor actions, is initiated and primed by the desired outcomes of the task and the initial conditions of the task. The appropriate response parameters for these are set in the motor response schema, activating a particular motor program. This movement in turn changes the *task environment* and this in turn produces the *outcome* which may be measured or assessed in some way.

Knowledge of results, that is, of the outcome, then indicates any deviations from the desired outcome, that is, *errors*, and these are labelled and followed, in Schmidt's model, by subjective reinforcement. In the adaptation presented here, errors are viewed as a source of self-regulatory actions which may modify the schema for the next trial. In a continuous action, which was not studied by Schmidt, in which knowledge of partial outcomes is available throughout the performance, error labelling and adjustment could presumably proceed continuously. The sub-schema evoked by the desired outcome and conditions, outlined by the outer loop of the diagram, was termed *recall schema* by Schmidt. There is a second sub-schema outlined by the inner loop. In this, the change in the task environment produced by the movement is taken to produce *sensory information*, or indicators, in the present case such as come from the sound of the arc or the appearance of the weld pool in MMAW. These indicators can then be compared with *what is expected* for the particular conditions, a comparison which may give rise to the observation of a different kind of deviation or error. This second sub-schema Schmidt termed a *recognition schema*.

How are these two schemata learnt? Each depends on learning particular correlations, albeit perhaps unintentionally. The *recall* schema is learnt through experience by correlating initial conditions, *response specifications*, and outcomes, the more variability in initial conditions, the faster the learning. Eventually, for given initial conditions, response specifications may be set so as to minimise error in outcome.

The *recognition* schema for particular initial conditions is learnt by finding what *sensory information* attends, for given initial conditions, particular outcomes . Once learnt, this constitutes the *expected* sensory information and it can in turn be used to judge the actual sensory information received in a particular trial. Thus, although the scaled and cleaned weld *outcome* is very different in appearance from the weld pool and its surroundings seen *during* welding, experienced welders can readily forecast what the outcome weld will be like. On a continuous task such as welding, the recognition schema should allow continuous adjustment of the manipulators, i.e. the motor program, so as to maintain desired expected sensory feedback.

Schmidt's notion of a recognition schema seems an important one in conceptualising task feedback. In broad terms, the question is: What bench

marks does a performer use to regulate action as he or she is actually doing it? In Schmidt's experiments these bench marks were perceptual expectations learnt by experience. In the case of welding, the situation seems very similar. But, for this skill, need these expectations be learnt *only* from experience? Certainly a good deal of effort is put into teaching apprentices first approximations to the *recall* schema, or the motor specifications, e.g. 'Hold the electrode at 60° to the weld line', or 'hold the electrode as close as possible to the job'. Such advice is intended to speed up the learning of the recall schema. Can there be a 'thinking' component also to the learning of indicators, i.e. the recognition schema, in which the learner is alerted by instruction, explanation, diagram, animation, on close-up video about what to attend to or look out for? Can a labelling process be used for specific indicators to provide a language by which teachers and students can exchange information about them? In our studies, we have made a start on such questions, as described below.

In the case of electrical installations, much of the monitoring process is conceptual rather than perceptual. What guides electricians is that their actions must continuously conform to safety principles, efficiency, correct following of the wiring plan, and the like. Task feedback consists in the on-going recognition of whether such features are present. The notion of monitoring activity *during* task performance, however, again receives little attention in curriculum and teaching. It may well be that the use of such monitoring could be studied in a wide variety of skilled trades and professions.

Approaches to encouraging learning

What has been argued so far is that describing the progression towards expertise, as it seems normally to occur, is not the same as understanding the means by which the progression takes place. Nor do general descriptions focus on the dimensions most appropriate for any particular skill domain. How isolated features are integrated by knowledge, how concepts influence the learning of skills, how proceduralisation occurs, and how people become progressively better at solving problems in their specific field are important questions. Two particular examples of what is learnt and how the curriculum may be structured have been based on the theoretical positions of Gott (1988) and Schmidt (1975). These two

approaches also suggest important learning models, the one concerned with the integration of understanding, strategies, and procedures in learning, the other with the use of task-feedback. To implement such ideas however requires an environment which nourishes them. It is this learning environment which is next dealt with by discussing two aspects as examples.

Helping apprentices to use task-feedback

Helping learners to discover what features of a task in progress to attend to in order to guide action has not been widely discussed in the literature. One way of dealing with the problem is to make a thorough analysis, from the expert's view point, of relevant *event information* (e.g. Flach, Lintern and Larish, 1990). Flach *et al* argued that this information can then be set out in a hierarchical framework, so that easy to perceive information, e.g. the sound of the weld arc, is high on the hierarchy and difficult to perceive information, e.g. indications of penetration, are lower. Such a framework could then form the basis of what the instructor actually encourages. Using Gibson's (1966) notion of 'attunement' as the education of attention, Flach *et al* went on to argue that it is useful to conceive training as 'guided exploration with the object of aiding the learner to discover the relevant event structures' (p330). *Exploration* is the operative feature. In many teaching situations, there is considerable emphasis on learning the 'correct' way, even in the early stages. This approach usually means modelling *actions*, rather than discovering event structures. There may, however, be considerable value in exploring both correct and 'incorrect actions', given of course adequate attention to safety. An example is altering the angle at which the welding electrode is held so as to learn to distinguish slag form metal. Such investigations may be critical to the rapid learning of indicators and their relationship with actions. A useful adjunct would be video or animation, but these themselves would not give the opportunity to correlate the perceptual consequences with actions. Another adjunct would comprise demonstration and drawing attention to both action and consequence, but this also alone does not give the learner the control over both action and consequence. Finally discussion, alerting the learner to appropriate monitoring information, although possibly weaker than other approaches may help. It is this last approach that we have tested in our studies so far (see below).

Assisted reflection

Progressive feedback is provided to apprentices as they perform tasks by events in the tasks themselves. In many cases this inevitable feedback is sufficient to promote learning, as most people know from teaching themselves a variety of skills. In substantial trade and professional areas, however, such feedback is insufficient to allow acceptable progress in learning for three reasons. First, not all aspects of performance may be able to be perceived by the performer, and knowledge of performance needs to be provided. Second, self-feedback needs to be augmented by knowledge which may be unavailable to the learner. Third, self feedback may benefit from assistance and prompts from others to help the learner to be more self evaluative and reflective.

In apprenticeship training, each of these functions, providing knowledge of performance, providing new information, and assisting self evaluation and reflection are tasks commonly performed by teachers and industry supervisors. They comprise a principal form of teaching. In general this activity is less formalised than other teaching because it must, by its nature be more responsive and flexible, and not subject to linear time allocations as is often the case with whole class teaching. It also involves close personal relationships, in which the instructor's role becomes that of mentor. These activities usually occur in short feedback sessions involving teacher or supervisor and apprentice, for example after a trial weld is completed, or after a board has been wired in electrical installation. They may also occur *during* a performance, or with a group of apprentices, particularly if there is an opportunity of providing new, currently pertinent, information.

One useful model for analysing the feedback session is that proposed by Ilgen, Fisher and Taylor (1979) in their review of research on organisational settings, which has formed the basis of much later research (e.g. Brinko, 1990) in other settings. The question to be analysed is: How does the learner utilise feedback? Ilgen et al argued that the process can be thought of in terms of variations in the source, the message, and the recipient over different aspects. They outlined a path from source through perception, degree of acceptance, desire to respond, forming goals, and, finally, to actually responding. Additionally external constraints may operate at each of these phases.

According to this review and later work (e.g. de Gregorio and Fisher, 1988), as far as *perception* of feedback is concerned, the recipient's *own* perceptions, feelings, and ideas (self involvement) have the most influence, followed by supervisor, co-worker, and formal appraisal, in order of effect. Additionally positive feedback is perceived more readily than negative. *Acceptance* of feedback is also heavily dependent on self involvement in the process (de Gregorio and Fisher, 1988), as well as on the trustworthiness of the source (Ashford and Cummings, 1983), on the accuracy of the data (Brinko, 1990), and on whether its content is positive rather than negative (Ilgen et al, 1979).

Whether the person *responds* to feedback or not does not necessarily follow from acceptance. It depends also on whether responding is worthwhile in the recipient's view (Ilgen et al, 1979) and on the person's control beliefs, particularly whether he or she believes there is a choice in undertaking the proposed actions and whether he or she believes that increased effort or change will be productive. This sense of *personal control* can be enhanced if feedback is generally positive, and if negative feedback is set between positive instances (Brinko, 1990), and if feedback is *self*-referenced, rather than involving comparison with others.

As to *goals*, these too depend on self involvement and development of the person's control beliefs (e.g. Bandura 1988). Feedback that is specific is more effective (Linden and Mitchell, 1985; Murray, 1987) and goals that are specific guide performance better than do general ones (Locke, Shaw, Saari and Latham, 1981). The type of goals finally set by the person is also important in the way learners approach the task. When the goal is to acquire new skills or to achieve mastery of the task to the point of independence, the focus is on processing task variables and maximising learning (Dweck and Elliott, 1983; Nelson-Le Gall, 1985). By contrast, when the focus of the activity is to obtain immediate satisfaction or merely fulfil a requirement, for example, obtaining a 'competent' rating, performers tend to focus not on learning but on comparison with others. In the former case help-seeking is valued as a way of increasing one's ability; in the latter, the person tends to avoid exposing weaknesses (Ames, 1983; Dweck and Elliott, 1983).

The two issues discussed above are both concerned with different aspects of feedback. They do not of course cover the whole range of issues concerned

with encouraging learning, and refer generally to the workshop setting. They promise, however, to be important foci for improving learning settings generally. Some empirical approaches to implementing the implications of the discussion are set out below.

Some empirical studies on promoting learning

The above analysis of curriculum and learning issues, particularly with respect to feedback, suggest a number of important criteria for judging interaction between instructor and apprentice. The instructor is likely to be a more useful mentor if he or she: (1) promotes a 'learning' rather than an 'assessment' ethos in the workshop, by referring *progressively* to more complex aspects of the expert performance and to underlying *conceptual* knowledge in discussing problems; (2) encourages continual monitoring of performance and helps learners become aware of what to look for in the process of monitoring (task feedback or indicators); (3) provides positive reinforcement and encouragement by valuing the learner's efforts; (4) ensures that the learner participates actively in the feedback process; (5) helps the learner attend, in feedback, to analysis of work outcomes and, where possible, to their relationships with preparation, method of performance, and indicators during performance; (6) encourages the setting of specific goals for the next and future trials on the task.

Pilot studies on the use of interaction features

Our research so far suggests that these six criteria are not always well met in the teaching process. In the pilot study with the sample of 11 Stage III and 8 Stage I metal fabrication apprentices mentioned earlier, and in the control groups of subsequent experiments with Stage II apprentices, in any group very few or no students actively analysed the weld for themselves, and few apprentices asked questions of the teacher. Generally, the teacher made a summary evaluation, pointed out faults, and explained faults in terms of relations between manipulators or preparation and outcomes. Reference to the weld pool or sound of the arc was made very rarely. Use of welding concepts such as heat transfer was absent. Where the teacher set

explicit goals, they were in terms of outcomes, preparation (e.g. 'grind the surface', 'change electrodes'), or manipulations (e.g. 'lower angle'); no goals were set in terms of the indicators. Our experimental work in both welding and electrical studies has been concerned with whether, if teachers adopted more closely the criteria set out above, apprentices might improve not only performance judged in terms of outcomes, but knowledge of the overall process in the expert models, particularly with reference to indicators or monitoring, ability to diagnose and understand faults, and self ratings of their own performance.

Electrical installation: preliminary experiments

In the case of electrical studies the technique we have used has been to use case studies of a single teacher (Evans and Butler, 1993), the teacher acting as his own control by teaching both a control group and a subsequent experimental group. Results so far suggest a significant improvement in outcome measures for the set college tests ($p=.037$), a board task involving identification and diagnosis of faults ($p<.005$), a card sort task concerned with identification of monitors ($p=.092$), and self assessed skills ($p=.050$). A second case study is now in progress. We have also been able to identify, by use of partial correlation methods, which of the interaction variables appeared to be most associated with improvement in the outcome variables. Perhaps not surprisingly, use of positive feedback and encouragement, thus valuing the students work, was most clearly the interaction variable that had most effort on each of the outcome variables (Evans and Butler, 1993). In a subsequent study that we are currently conducting, the teacher is using the other interaction variables mentioned above much more frequently. What both teachers have found to be the most difficult interaction variable to use more frequently is the setting of goals by students. In either case, the effect of the intervention has been to reduce the number of goals that the teacher imposed throughout the training session but without a corresponding increase in the number or relative proportion of student set goals.

Welding workshops: preliminary experiments

The welding training studies used a different approach. We were not able to obtain the same condition of each teacher acting as his own control. Rather we have allocated teachers to experimental or control groups and have been gradually increasing the number of classes with which we have worked. This means that the extent to which the 'experimental' or 'control' treatments were actually implemented is confounded with the teacher's usual style.

Quantitatively, we have sought evidence that teachers can introduce the idea of indicators into their teaching in a way which results in increased knowledge about them on the part of the apprentices. We have assessed this knowledge by means of a card sorting task that asks the students to sort the same terms as those involved in Figure 3.1, together with 16 extra cards referring to features of the weld produced. We asked the students to sort the terms first into those they would normally use or talk about during 'stick' welding (MMAW) and those they would not use. Using the former they were then asked to sort the cards into those containing actions or features they would use *Before Starting*, *During Welding*, and *After Welding*. They next subdivided the 'during welding' cards into two further groups: (a) look and listen — 'These are things to look for and listen for which tell you how the weld is going' and (b) *You can adjust* — 'These are things you can adjust as you weld'. This allowed us to distinguish what the apprentices saw as indicators (a) from manipulators (b). The score on *indicators* was the proportion of cards correctly identified.

We have also been using measures of the apprentices ability to observe faults and diagnose them. We present apprentices individually with four specimen 'horizontal fillet' welds exhibiting in all 31 faults on which six teachers reached a high level of agreement. We asked the apprentices to nominate the faults (weld assessment) and to say how they could be prevented (next weld) for each specimen weld. In terms of welding performance, we sought both a self rating (average of three questionnaire items) on a five point scale and a measure of performance on a trial weld ('vertical fillet up'), each of which was rated by a panel of teachers. All measures (indicators, weld assessment, next weld, self rating, and test weld) were made at the beginning (pre) and end (post) of a seven week period in

which the apprentices had a block release from their work place to pursue college studies for the particular year of their apprenticeship.

During that time, the experimental groups were given extra information on indicators in class and indicators were mentioned more explicitly as part of the feedback session. As a measure of implementation, we found that the indicators were mentioned in 11 per cent of interactions in the experimental groups compared with 3 per cent in the control groups.

Apart from content, the teachers in the experimental groups were asked, in line with the earlier discussion on assisted reflection, to ensure greater active student participation (sharing) in the feedback sessions on students' trial welds and to encourage the setting of more specific goals on the part of the apprentices in these sessions. In each case we undertook a short training session with the teachers involved and in the course of the workshops provided prompts for the teachers on how they might more effectively implement more attention to indicators, greater student participation in construction of feedback, and more setting of goals by students.

So far we have data for experimental groups from two colleges, A (N=21) and B (N=11) and two control groups (C, N=12 and D, N=13). Group D was not available for the post test on the trial weld. Groups A, C and D were from the same college and Group B from a different college.

The results were analysed by using analysis of covariance, so that post-test measures could be adjusted using pre-test measures as covariates. The results for the adjusted post-test measures (see Evans and Butler, 1992) may be summarised as follows, in each case the experimental group mean appearing first:

Indicators:	means	.72, .51	p=.003	effect size = .72
Weld assessment:	means	.70, .59	p=.09	effect size = .42
Next Weld:	means	.63, .50	p=.03	effect size = .56
Self Rating:	means	3.64, 3.39	p=.12	effect size = .40
Trial Weld:	means	66.8, 66.2	p=.85	effect size = .06

These results show that the results for the combined groups were in each case as expected, except for the trial weld, where the expected difference

failed to materialise. In each experimental group, the apprentices improved their knowledge of indicators; they performed better than the control on the weld assessment task and the 'next weld' task; they had somewhat higher self ratings than the control groups, the difference approaching statistical significance.

However, they did not perform better than the control group on the trial weld. The reason for this requires further research. On the post-test measure for the trial weld, Experimental Group B outperformed *both* Experimental Group A and Control Group C (means: B, 72; A, 64; C, 66), the effect sizes for A and B being — .28 and .70 respectively. That is, Group A was even a little worse than the control group, although not statistically so ($p>.50$), while the Group B mean was greater than the control mean, the difference approaching statistical significance ($p=.10$).

In Experimental Group B, student participation and goal setting were both significantly greater than for Experimental Group A, and both were better than for the Control Group. The effect sizes for student participation were B, 1.28 and A, .42, and for goal setting, B, .44 and A, .13. It may be that the implementation of both of these experimental treatments in Group B was sufficient to bring about the improvement in welding performance. We are currently adding new groups to this study and gathering further information on how apprentices actually implement the advice from their teachers in order to explore these effects further.

Summary and conclusion

The aim of this chapter has been to examine issues of curriculum and learning in trade skill programs which do not appear to be addressed in current discussions and implementation of competency based programs. In skill areas, these programs are constructed on the premise that what counts in the long run is people's ability to perform valued tasks in real world industrial settings. It is hard to argue with this premise at a general level, but treated superficially it could lead to counterproductive procedures in training and education. First, what is required is *repeatability* of performance. The better the person is able to control performance through understanding and use of within-task indicators, the more likely it is that repeatability will be achieved. Second, there are hardly any situations

where the ability to perform *just* specific fixed procedures is adequate. There is always some degree of novelty, and certainly there will be increasing needs for change in operations and procedures to meet the needs of new technology and challenges for increased efficiency.

Thus while learning skilled procedures in authentic settings is important (see Billet, this volume), so is developing understanding of procedures in such a way as to allow transfer to new settings and applications. One first line of attack in this problem is to understand the deep structure of expert performance. Such understanding is unlikely to develop from simple task analysis of expert performance. It also requires knowledge of the perceptual and conceptual knowledge involved in the task and in its applications. In this paper, in the case of welding, perceptual knowledge has been demonstrated; in the case of electrical installation, it was more conceptual knowledge. Both of these features could be profitably explored in the development of competency based curricula.

Further, even deep understanding of expert performance does not guarantee a satisfactory curriculum. There is a need to develop optimal pathways, possibly multiple pathways, in the tasks aimed at helping learners develop from novice to expert. Such curricula would be expected actually to intervene in beneficial ways in the learning process, by presenting ladders of tasks and understandings. In addition, to make progress the learner needs to develop strategic knowledge both in terms of knowing what to do when, and in terms of learning to learn. Such strategic knowledge may best be learnt in social settings emphasising self analysis and critical reflection.

The means of introducing such features into the curriculum need to be carefully assessed. Efficient means of presenting information — procedural, perceptual, and conceptual — obviously are needed. These may include diagrams, videos, and computer graphics and animation that direct attention to critical features. What also is needed are ways of helping apprentices to process such information actively. It is on this that the empirical work described briefly above has concentrated. There appear to be important ways in which teachers can use workshop settings to encourage active learning: promoting a 'learning' rather than 'assessment' ethos; providing encouragement and positive feedback; using progression in expectations of procedures, concepts, and perception; encouraging particularly use of monitoring procedures, or indicators, akin to expert

performance; and most particularly encouraging apprentices to think actively about their work products and what contributed to the features in these products.

Emphasising these approaches has been shown to be effective in some learning situations. If they can be shown to be effective in the teaching and guidance of apprentices, then our work suggests there is room for improvement in them in TAFE teaching and possibly in industry training. Our studies so far have been aimed at exploring the utility of some of these approaches. We are currently collaborating with teachers and industry trainers to develop ways in which conceptual and perceptual knowledge associated with welding can be more effectively integrated with workshop tasks, and how student participation, goal setting, and encouragement can be more utilised in workshop discussions.

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4 Train simulators and the development of expertise

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Abstract *This chapter examines the problem of how to develop expertise in drivers of long haul diesel electric trains, so that they are adaptable. The problem is explored by investigating the cognitive structures and processes needed when driving train simulators. Two studies are reported: one which analyses verbal protocols collected from a driver while driving a simulator over a seemingly problematic section of track; and a second which analyses the protocol of a driver diagnosing a problem faced by another driver.*

Together the studies illuminate the processes of forward and backward reasoning used by expert train drivers, and extend theoretical understanding. It is argued that, to develop expertise which leads to adaptability, training situations need to be provided which encourage the development of backward reasoning within a functional context. Through this means, better developed forward chaining (required for routine performance) is assembled, as well as richer links between concepts and procedures and the functional context (required for non-routine performance). There are many challenges in designing courses which incorporate these features.

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Introduction

This chapter is concerned with the problem of developing expert drivers of long haul diesel electric trains for Queensland Rail, so that they become accomplished at driving under routine conditions as well as capable of dealing with non-routine or problematic situations. This problem is explored by investigating the cognitive structures and processes needed for expertise by drivers as they drive train simulators. In this chapter it is argued that backward chaining is an important component of dealing with problematic situations and that, to develop adaptability, drivers need to be pressed into using backward reasoning, at least in situations where

propositional knowledge is central. The question of whether backward reasoning is applicable in situations which are highly procedural requires further research. The implications of this research for other training situations are also explored.

The prime goal of train driving is to arrive at the destination safely and on time, while maintaining smooth progress and consuming as little energy as possible. Many aspects of driving over a particular section of track are routine; for example, there are well practised actions for starting the train and for blowing whistles. However, some procedures are particularly variable in their application, and the conditions under which they are applicable can be complex. For example, the way in which the air brakes are used is highly variable because of the characteristics of the pneumatic wagon braking system and the long time delays between brake application and speed reduction, particularly on trains over a kilometre in length. Furthermore, drivers do not always drive on the same 'road' and, even in familiar territory, non-routine circumstances also occur frequently. Every train has unique characteristics with respect to engine performance, behaviour of brakes and wagon couplings, and size and distribution of load. Features external to the train are also variable. Signal positions vary depending on the schedules of other trains 'on the road' and weather conditions can greatly affect visibility and the friction between wheel and track. The interaction between variable train characteristics and external conditions leads to situations which are not entirely predictable and which require non-routine behaviour on the part of the driver who is striving to achieve competing demands. On variable track, decisions to regulate speed must be made continuously in the light of conflicting demands for safety, smooth progression, fuel economy and schedules. See Middleton (Chapter 5) for a discussion on conflicting demands in complex problem-solving.

The need for adaptability on the part of drivers scheduled to drive different trains under different conditions occurs over a time span of a few hours, days or weeks. Moreover, Queensland Rail, in common with many other employer groups, requires greater adaptability of employees in the longer term, as award restructuring and job redefinition proceed. For example, new work practices to reduce staff levels through two-man crews or driver-only operation result in widened job responsibilities for drivers. The introduction of new technology also demands increased adaptability on the

part of drivers. There is the need to perform under changing conditions caused by the introduction of new models of locomotive and other rolling stock, new or realigned sections of track, station and depot closures, electrification of track, new signalling and communication systems, changed control operations and computer based locomotive control (e.g. Locotrol). With advances in technology, the rate of change in work situations is unlikely to slow down. The skills and knowledge of train drivers (and other employees) need to be upgraded, but not just by increasing the amount of knowledge. Rather, what is needed is instruction which integrates knowledge and encourages flexibility and problem-solving, so that new situations can be faced and dealt with as they arise. As argued elsewhere (Stevenson & McKavanagh, 1992), what is needed is an expert work force which is adaptable.

In arguing the case that pressing learners into using backward chaining promotes the development of adaptability, this chapter examines cognitive structures and processes needed for expertise, and reports studies of train drivers engaged in driving a train simulator and in explaining what other drivers did. Firstly, however, the use of simulators in training is examined.

Train simulators

Simulators replicate portions of reality in a controlled environment. Essential characteristics of a task or situation are duplicated to allow interaction and control by users. Simulation is a 'process of conducting experiments on a model of a system' (Mize & Cox, 1968) and the 'manipulation of a model to reproduce its operations on a set of data as it moves through time' (Gibbs, 1978). Simulation 'allows the user to experiment with systems (real or proposed) where it would be impossible or impractical otherwise' (Shannon, 1975).

Simulators have been widely used in workplace training, for example in the nuclear industry (Widen & Roth, 1992); air traffic control (Seamster, 1992); and for aircraft pilots (Thomson, 1989). The range of simulations include abstract and mathematical models, information models of relationships among business groups and models of complex mechanical systems. Only real-time, dynamic simulators of mechanical systems, such as whole trains,

are considered here. These systems are interactive and provide immediate feedback to operators.

A train simulator models a train-in-motion in real time. Interaction with this system allows a driver to develop and practise skills, test various driving strategies, and to receive immediate and detailed feedback on driver and train performance under controlled and reproducible conditions. Simulators can reproduce characteristics of a complex mechanical system, encourage human interaction with the system and provide feedback which is often more detailed and helpful than normally provided by the realities of the working situation. While training using real trains may be desirable, simulations may be preferred because of cost, safety or other reasons (Hopkins, 1975).

Hence, train simulators have the potential to facilitate the development of expertise by train drivers with responsibility for train handling and fault rectification.

Fidelity

The question most often raised about the performance of a simulator is that of its fidelity. This refers to the degree to which the simulator faithfully represents the characteristics of the system being modelled and experimented upon. Hays and Singer (1989) provide a formal definition:

> *Simulation fidelity* is the degree of similarity between the training situations and the operational situation which is simulated. It is a two dimensional measurement of this similarity in terms of: (1) the physical characteristics, for example, visual, spatial, kinaesthetic, etc.; and (2) the functional characteristics, for example, the informational and stimulus and response options of the training situation. (p. 50)

High degrees of fidelity are associated with high costs and, in the purchase of simulators, it is tempting to seek the highest degree of fidelity that is possible with current technology. As Alessi (1988) points out, 'Since the real situation is most 'similar' to itself, it has been assumed by some to be the best instructor.' (p. 40). However, Alessi has also shown that there is not a

simple relationship between fidelity and training effectiveness. Moreover, since simulators can provide features which are not available in the situations being mimicked, training using simulators can be more effective than using 'the real thing'. For example, driver-trainers within Queensland Rail report that an air brake simulator, which shows the positions of brake blocks in relation to the wagons, is particularly effective in teaching braking techniques. Apparently this is because the simulator makes explicit information not normally available to the driver. The driver can see the movement of the brake blocks under the wagons and the time delays between brake lever movements, brake application and release of the blocks. Through these means, a more accurate mental model of braking actions can be constructed.

Thus, in a training environment, focusing only on the question of fidelity is misleading, since high fidelity is not really the goal. As Bunker (1978) points out, 'instead of pondering how to achieve realism, we should ask how to achieve training' (p. 291). Accordingly, the achievement of high fidelity, while linked to the question of training effectiveness, should not be allowed to hijack the debate on what constitutes training quality. Simulators with limited fidelity can be used to good effect, even though they may not be able to be used for all aspects of training.

The nature of expertise

In this section, the nature of expertise is discussed in terms of cognitive structures and processes which use these structures, as pertaining to train driving and the use of train simulators.

Expertise in driving

The important characteristics of expert train drivers are their ability to minimise fuel usage, to achieve a smooth ride and to arrive safely and on time. If high levels of expertise could be achieved by drivers on all these criteria, then the railway would make huge savings on fuel, wear and tear and damage to goods, and would substantially improve its image with freight and passenger customers. Even modest improvements in expertise by the majority of drivers would bring large savings, better public relations

and more custom. The cost of a simulator could be recouped if only one serious accident could be avoided through more effective training. Further, drivers's control over their driving would be more personally rewarding. Improved training of drivers, centred on attaining high levels of expertise, remains a high priority corporate goal.

In train driving, planning ahead is an important skill in the development of expertise. Advanced planning is essential in achieving energy efficiency, a smooth ride and in meeting safety requirements while arriving on time. Through advanced planning both acceleration and braking can be minimised, without sacrificing average speed. Stretch ('draft') and compression ('buff') forces can also be minimised, so reducing wear and tear on track and rolling stock, and minimising damage to goods and discomfort to passengers.

Because of the complex relationship among subsystems of the train, as well as the interaction with road knowledge, real trains on real tracks or simulators which display tracks, are needed for effective instruction in train handling. This is especially true for complex and non-routine situations. It is also true for novice drivers who have less well developed routine skills and who must retain more knowledge in working memory, in order to predict train behaviour, and coordinate the various subsystems, to control speed and the stretch of the train. Simulators, in which the degree of complexity of information can be controlled, provide a way of limiting information overload until novices have automated some of their procedures, and so can direct more working memory to deal with the complexity of the task.

Road knowledge and driving skills

In driving and in monitoring the train and driving performance, a driver uses information from cabin noise, the view of the track and the many cabin gauges. See Evans (Chapter 3) for a discussion on such perceptual feedback. The driver also depends on memory for information about rules and regulations and for what lies ahead on the track. The 'road knowledge' is particularly critical for driving expertise, since braking times are slow (it can take 1.6 km to stop a 1.6 km freight train from a speed of 80 km/hr), and signal and speed limit signs usually occur only at the locations from

which they become effective, rather than in advance. Printed 'road maps' are not readily available to drivers and, in any event, would not relate landmarks to road conditions or driver actions. Advanced warning about the locations of signals and signs is not usually given along the tracks. Drivers must rely on their memory to know what lies ahead. They must constantly use this knowledge to plan and execute actions, now, that will have their full effect after the next corner or over the next crest. Expertise in driving is dependent upon a thorough knowledge of the road. This knowledge consists of both information (propositions) and strategies for dealing with situations (procedures), as well as complex relations among propositions, procedures and perceptual feedback from the functional context in which they are driving.

It may appear from observing expert drivers that driving actions are routine and automatic without the need for thinking skills, such as planning ahead and problem-solving. However, research conducted using diesel electric simulators in Rockhampton makes it clear that drivers engage in a great deal of cognitive activity, such as planning, predicting and monitoring, especially under varying track conditions or when learning new track. That driving requires a high degree of cognitive processing is further supported by the fact that experienced driver-trainers report that even very skilled drivers cannot play chess at the same time as they are driving on track with changing characteristics. There is continuous interaction among road knowledge, knowledge of train characteristics and behaviour, and driver actions. Therefore, only driving on real tracks or on simulators which can represent track knowledge (the electric simulators with computer generated graphic track display or diesel electric simulators with videodisk display of actual track) are useful for learning train-handling skills.

For freight trains especially, manipulations to slow the train are particularly complex, with interaction effects of the three different braking systems (dynamic, wagon and locomotive brakes). The length, weight and speed of the train, the condition and grade (slope) of the track, the distribution of the load and the type of brake valves fitted all affect braking capacity. Also, it takes a considerable time for the brakes of the rear wagon to engage after brake air application, as the propagation must travel through the pressure pipe along the length of the train. Furthermore, once air pressure is depleted, further air brake application is ineffective.

Thus, an instructional setting involving train simulators which, while providing a high degree of control over initial conditions, engage drivers in cognitive activity and which output a detailed range of intermediate and final variables, is ideal for a cognitive approach to the design and implementation of instructional programmes. For example, graphic displays and run printouts from electric and diesel electric simulators show changes in track characteristics, driver actions, train reactions and train forces every few seconds. Driver actions, track characteristics and train dynamics can be monitored; and detailed feedback can be given. Discussion linking all these aspects can be conducted with drivers and analysed in a way that is not possible under on-the-job conditions where the demands of the next part of the journey must take precedence over analysis of the previous section of track.

Cognitive structures for expertise

Experienced drivers display substantial routine, almost automatic behaviour, such as pressing the vigilance button every ninety seconds to prevent the alarm from sounding. The demands of the job also require such non-routine behaviour as adapting not only to different types of locomotives, different roads and road conditions, different weight distributions of trains and different braking characteristics, but also to less predictable situations such as temporary changes to speed boards, train faults and obstructions on the line. In terms of learning theory (Anderson, 1982, 1990; Scandura, 1981; Stevenson, 1986a, b) routine behaviour relies on knowledge of how-to-do-it or specific procedures, while non-routine behaviour relies on strategic knowledge or higher order procedures as well as specific procedures. Both types of behaviour also rely on conceptual knowledge about situations and devices (propositional knowledge) which is knowledge that can be recalled without being carried out. Typically novices in a field have less well developed propositional and procedural knowledge than do experts, and are less able to develop effective plans to meet new or unexpected circumstances (Chi, Glaser, Rees, 1982; Gagné, 1988; Glaser, 1984).

The problem of how to develop both routine and non-routine aspects of expertise raises questions of the nature of expertise. Stevenson (Chapter 1) has defined technical expertise as 'the ability not only to perform routine technical skills, but also to:

- generate and evaluate skilled performance as technical tasks become complex and as situations and processes change,
- reason and solve technical problems,
- be strategic,
- innovate and
- adapt.'

He also argues that, in addition to interest and motivation, the following cognitive structures and relationships are needed for expertise:

- well developed specific procedures;
- ability to use higher order procedures;
- deep conceptual understanding at different levels of abstraction;
- rich associations between conceptual understanding and procedures; and
- embedding of understanding and procedures within a variety of functional contexts.

Further, for the development of expertise, these structures and linkages must be developed out of what learners already know, through an active construction of knowledge. Higher order procedures are brought into play whenever problematic situations are faced (Evans, 1991; Stevenson, 1986a,b, 1991; Stevenson, McKavanagh & Evans, Chapter 7), and these higher order procedures are necessary for expertise. Affective factors are also recognised as critically important, and motivation to learn is strongly influenced by the kinds of relationships existing between prior knowledge and interest.

Using this framework, expertise of train drivers can be viewed in terms of cognitive structures required to perform the job well under a wide variety of conditions. Of concern, then, are the dispositions such as interest and motivation which a driver brings to bear on learning about changes; propositional knowledge in the form of facts, concepts and principles, such as knowledge of engine controls and physical principles, with which the driver understands and communicates about the world of work; and procedural knowledge in which is encoded the executable physical and thinking processes that may have behavioural outcomes — such as looking at an instrument or applying the brakes. All this knowledge needs to be linked together and situated within real driving tasks — the driver must

know when, where and how to act and be able to predict the consequences of actions.

Research on cognitive processes in complex training environments has established that mental models, based on propositional and procedural knowledge, are important for expert performance in technical domains. For example, Gott (1989) has shown that experts have well developed procedural (how-to-do-it) knowledge, device knowledge (declarative or knowledge 'that') and strategic (how-to-decide-what-to-do-and-when) knowledge. Well developed memory structures are required and the memory components must be linked to well practised performance skills in order to achieve goals. In a cognitive sense, Gott's work has demonstrated that these characteristics of expertise are common across such diverse activities as piloting aircraft, air traffic control, troubleshooting and tactical planning. All these domains have in common effortful performance and striving to fulfil goals on the part of the expert. This is not to say that such structures are directly transferable (rather, they are embedded in functional contexts), but to observe that common categories of structures denote expertise. Well developed memory structures are required and the memory components must be linked to well practised performance skills.

There is a need in vocational education for the development of three kinds of knowledge: knowledge about objects, concepts and ideas (propositional knowledge); knowledge for performance of specific tasks (specific procedures); and more general knowledge of how to work out what to do (higher order procedures) (Stevenson, 1991). Stevenson has also demonstrated that learning environments which press students into developing higher order procedures lead to adaptability, which he defines as 'the ability to use existing knowledge in a new way.' (p. 145). As discussed above, adaptability is of particular importance in the face of change, such as is now happening with widespread restructuring of the work force.

Information processing

The processes of expert performance can be cast in terms of information processing theory. Both routine and non-routine aspects of expertise are captured by this perspective. The routine aspects are sometimes referred to as 'routine cognitive skills' (Card, Moran & Newell, 1980). Non-routine aspects are referred to as problem-solving, which Anderson (1993) and Newell (1980) have argued is central to all higher level cognition.

One of the most influential theories of information processing was developed, primarily at Carnegie Mellon University, by Ericsson and Simon (1984); Greeno and Simon (1988) and Newell and Simon (1972). The theory centres on the notion of a problem space bounded on the one side by an initial or given state and, on the other side, by a goal or solution state. In working towards a goal, the individual transforms the current state by acting upon it. The aim is to perform successive state transformations until the desired state is attained. In routine situations, the path is well worn and progress towards the goal is smooth. Where new or non-routine situations are encountered, the path may not be linear, and trial and error and backtracking may be necessary. Nevertheless, an expert is generally capable of moving from the initial state to the more distant goal state. Experts are viewed as having a well developed knowledge base containing structured propositional knowledge and specific procedures which can be quickly applied in progressing towards the goal. The expert has a range of strategies for bringing relevant propositional knowledge and specific procedures to bear on the problem.

For example, an ever present goal for driving a train safely and on schedule is to keep close to the speed limit without exceeding it. However, because of the complexity of the pneumatic braking systems on long diesel electric trains, the time delays between action and effect, and the interactions among train sub-systems, load and environmental conditions, the achievement of this goal is often problematic. Routine procedures are certainly used, but these must be strategically applied and varied under non-routine circumstances.

Information processing strategies can be divided into strong and weak methods. Anzai (1991) sees this as a fundamental distinction:

> Weak methods are general methods independent of domain-specific knowledge and include generate-and-test procedures trial-and-error search, means-ends analysis, and problem reduction. Strong methods involve various strategies to exploit domain-specific knowledge to find an efficient solution. Because virtually no one possesses the full range of domain-specific knowledge of physics, even an expert physicist should use weak methods when strong methods cannot be applied. Actually, Larkin (1977) found such behavior empirically. She had several physicists solve problems that were novel to them and she found that most of the physicists used general, weak methods to find adequate initial representations of given problems. (Anzai, 1991, p. 71).

These strong and weak methods can be related to forward and backward reasoning processes. According to Patel and Groen (1991), during forward reasoning in medical diagnosis, experts '... tend to work 'forward' from the given information to the unknown.... 'Forward' reasoning usually is contrasted with backward reasoning, in which the problem-solver works from a hypothesis regarding the unknown back to the given information.' (p. 93). While the term 'backward reasoning' is widely used in the literature, it should be noted that it is somewhat of a misnomer, since the process is future oriented and directed at fulfilling a goal. Backward reasoning focuses on what is desired and what steps will need to be accomplished to achieve the goal. The relationship between strong and weak methods and the problem space is depicted in Figure 4.1. In this conceptualisation, the left hand side of the figure represents action in routine situations and involves strong methods, forward reasoning and specific procedures. The right hand side of the figure represents planning for action in non-routine situations and involves weak problem solving methods, backward reasoning and higher order procedures.

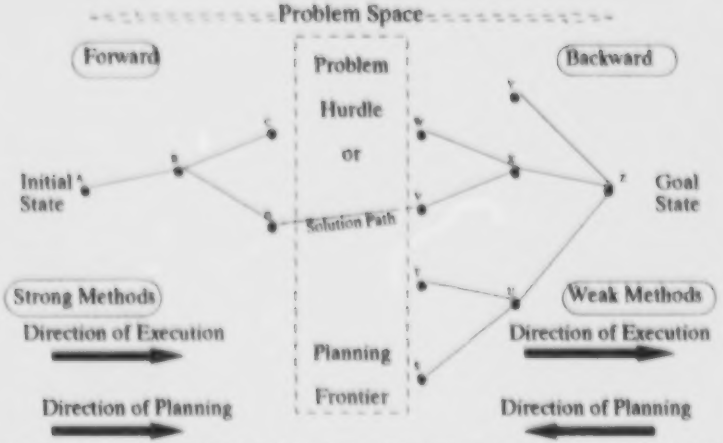


Figure 4.1 **Postulated relationship between the problem space and strong and weak methods**

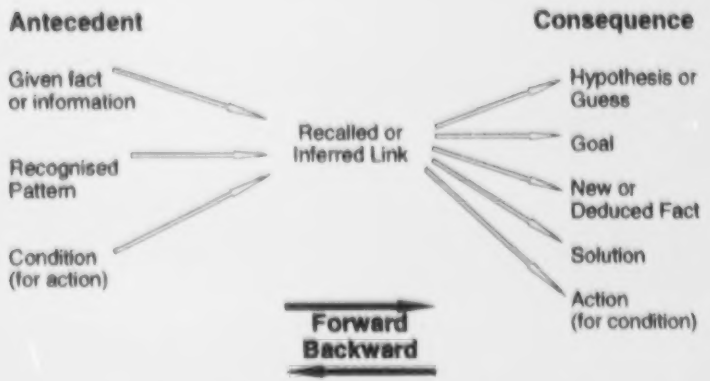
In this diagram, each lettered dot represents a state and each link between a pair of dots is a transformation from one state to another. The direction in which the links are assembled and used is the basis of forward and backward reasoning, or, as it is referred to here, as chaining. To help elucidate the nature of this chaining, publications of Groen and Patel (1988, 1991) and Patel and Groen (1991) were searched for various quotations of forward and backward reasoning. Those identified are categorised as shown in Table 4.1. With the exception of the last quotation, which refers to 'rules', each represents a directional link between two elements. The directionality of the link determines whether forward or backward coupling is involved. A forward link is one in which the connection is either away from the initial state or is towards a desired state or both. A backward link is one in which the connection is either away from the desired state or is towards an initial state or both.

TABLE 4.1: Quotations for forward and backward reasoning

Quotation	Source	Code*
Backward Categories		
'works from a hypothesis regarding the unknown back to the given information' 'experts and novices used a form of backward reasoning akin to the hypothetico-deductive process'	Patel & Groen (1991) p. 93 Groen & Patel (1988) p. 288	BHF
'the distinction is frequently made ... in terms of goal-based (backward) versus knowledge-based (forward) heuristic search' 'reality assessment in which the validity of a hypothesis or the attainment of a goal is checked against the given facts'	Patel & Groen (1991) p. 93, p. 36	BGF
'an attempt is made to obtain further facts .... this backward reasoning can also be used by experts, especially when their knowledge base is inadequate to reach a satisfactory solution immediately'	Groen & Patel (1991) p. 36	BSF
Forward Categories		
'work 'forward' from the given information to the unknown' 'from facts to a solution .... the distinction is frequently made .... in terms of goal-based (backward) versus knowledge-based (forward) heuristic search'	Patel & Groen (1991) p. 93, 36	FFG
'from a given or already deduced fact about a situation to one that is new in the sense that it is neither given nor previously deduced'.	Patel & Groen (1988) pp. 287-8	FFN
'the superior recognition (of patterns) results in the ability to do forward reasoning'	Patel & Groen (1988) p. 288	FPS
'An individual will apply these rules by a process of forward reasoning' 'A simple test for forward reasoning was to discover whether these rules would correctly execute when implemented in a standard forward-chaining production system interpreter'	Patel & Groen (1988) p. 292, p. 300	FCA

* These codes are used in the data analysis from the diagnostic study as described later in this chapter.

By decomposing the term 'rule' into its constituent parts, the last quotation could also be united with this conceptualisation of forward and backward chaining. Following the work of Anderson (1982) and others, a rule is interpreted as an antecedent-consequence production, but in declarative form. Anderson's work postulates that productions may be in either a declarative or procedural form or both. In the context of the verbal protocols reported later in this chapter, rules are seen as declarative because they are verbalised and reasoned about, rather than being executed by the subject. Thus, in this context, rules are of the same form as other declarative statements made by the subject. These rules are conceived as a linkage between a condition and an action — the action can be executed if the condition is satisfied. For a rule to fire, the condition must be the current state. The firing of the rule leads to an action and a change of state closer to that desired. Therefore, a rule is a forward link in a form consistent with other types of forward and backward linkages as described above and depicted in Figure 4.2.



(After Groen & Patel 1988, 1991; Patel & Groen, 1991)

Figure 4.2 Conceptualisation of Forward and Backward Links

In routine situations the steps to take to reach the goal are well known and can be assembled in a forward direction from initial state to goal state. The

goal can be achieved by executing the steps along this path. In non-routine situations, however, a complete path is not so easily assembled. Forward chains and backward chains both need to be assembled. Only when a forward and a backward chain meet across the problem hurdle can the initial state be transformed into the desired state and the problem solved.

Relationships between cognitive structures and information processing

The relationships between cognitive structures and their use in information processing can be illustrated as in Figure 4.3, depicting an expert's knowledge structure. This figure represents a vertical (third dimensional) expansion of Figure 4.1 and a transformation of the problem hurdle from a line to a circle, thus generalising the 'unknown' region of the problem hurdle so that many goals can be represented.

In Figure 4.3, two planes are represented — a conceptual plane of propositional knowledge and a procedural plane of specific skills. (More levels of the conceptual plane could also be introduced to represent the 'deep conceptual understanding at different levels of abstraction' posed by Stevenson in Chapter 1.) The space outside of the circle on the conceptual plane represents knowledge unknown to the subject and the interface between the known and unknown represents the region of planning and testing of ideas (here called the planning frontier). The central circle of the procedural plane represents actions ('can do') which corresponds with well developed specific procedures. This central area is surrounded by a problem hurdle which would need to be overcome to actually perform new skills. Also in the figure is a cylinder depicting a link between the 'known' of the conceptual plane with the 'can do' of the procedural plane. This cylinder represents one linkage between a proposition and a procedure, i.e. one of Stevenson's rich associations between conceptual understanding and procedures. Thus concepts in the 'known' area may have corresponding procedural projections in the lower 'can do' area and vice versa. However, links between the conceptual and procedural may not have a one to one correspondence. For example, one concept may have many procedures attached to it and vice versa. Furthermore, particular concepts may have no corresponding procedures. This situation is represented in Figure 4.3 by a

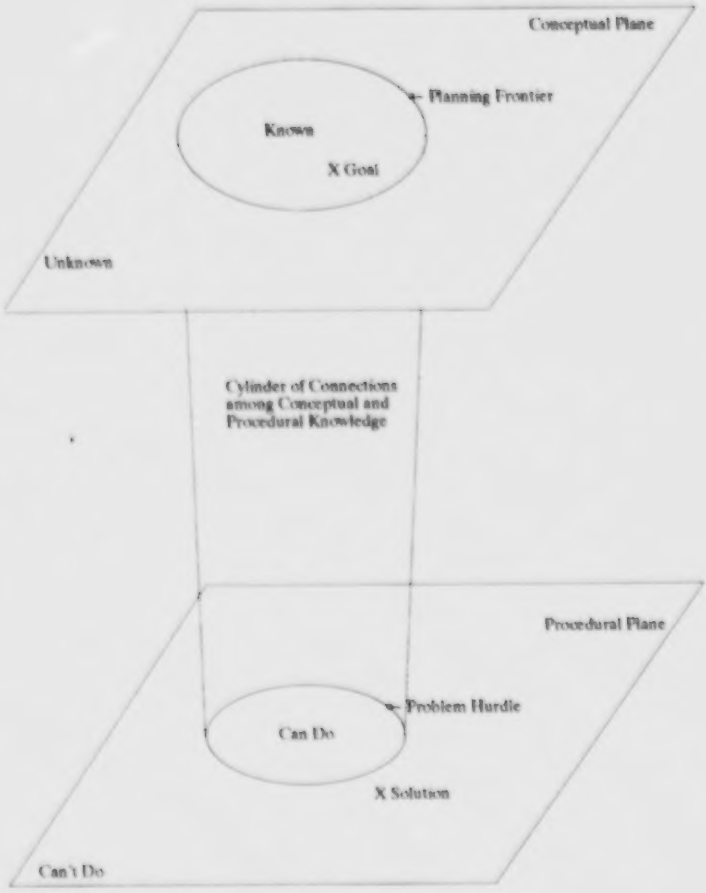


Figure 4.3 Roles of Cognitive Structures and Information Processing in Expertise

goal 'X' inside the 'known' circle of the conceptual plane (e.g., quickly and safely slow a heavy train on a particular downhill section of track) and by an 'X' outside the 'can do' circle of the procedural plane. In this case the meaning would be that the driver knows about this goal (i.e. knows what the goal is and may even be able to describe some relevant activities), but does not immediately have the skills to quickly and safely slow a heavy train on a particular track.

The remaining element of Stevenson's conceptualisation of expertise is that of the ability to use higher order procedures. In terms of Figure 4.3, it is the use of higher order procedures which enables the solving of problems. It is the nature of these higher order procedures which is of prime concern here. It is argued that higher order procedures induce the use of backward reasoning and that training which helps develop backward reasoning will lead to better developed forward reasoning and specific skills, and richer conceptual links among knowledge structures. Learning which results would be represented by the enlargement of the individual's 'can do' circle; or the enlargement of the 'known' circle of conceptual knowledge; or the establishment of richer links among the knowledge structures.

Forward and backward reasoning processes

As outlined above, prominent in recent research on expertise is the use of forward and backward reasoning by novices and experts. For example Larkin, McDermott, Simon and Simon (1980) found that, in solving physics problems, novices tended to work backward, using a means-ends strategy. Although novices tended to work backward, Larkin et al. (1980) also found that experts tended to work forward. Rather than constructing a chain of equations from the goal back to the givens, experts began by choosing equations that allowed immediate calculation of values. They worked forward from the givens to the goal and performed the calculations in the same order as the order in which they were selected. In this case, the direction of extending the chain is in the same direction in which the actions are performed (See Figure 4.1).

In reviewing the expert-novice literature across a number of domains, Chi, Glaser and Rees (1982) established that experts tend to work forward and have better organised schemata, with hierarchical goals and productions, than do novices, who tend to work backward. However, Groen and Patel (1991) have shown that backward reasoning is used by both novices and experts in non-routine situations, so that backward reasoning seems to be characteristic of reasoning about new or non-routine situations rather than of novices per se. This is also reinforced by the findings of Elstein, Shulman and Sprafka (1978) who reported that both experts and novices used a form of backward reasoning akin to the hypothetico-deductive process often advocated as a paradigm of scientific reasoning.

Each link in the chain is regarded as a production (Anderson, 1982) which consists of a condition-action pair. A condition action pair is a form of the more general requisite-consequence (or antecedent-consequence) pair of procedural networks, such as those postulated by Sacerdoti (1977), and developed as action schema by Greeno, Riley and Gelman (1984). Productions may be the result of a stimulus-response behaviour sequence (Chi & Rees, 1983), adapted to a frequently occurring situation. The process of search during cognitive activity is concerned, initially at least, with finding conditions of if-then productions that match the current state. In the words of Hunt (1989), 'Production system modelling puts the burden of problem-solving upon the pattern recognition system.' (p. 611). If the search is successful, the corresponding action is then taken (i.e. the production fires). Thus, where a match results from a search forward from the givens, an immediate response can follow.

Chi, Glaser and Rees (1982) suggest that, perhaps, experts have automated their backward solutions and describe, as follows, Larkin's (1981) Barely Able computer model for forces and energy problem-solving, that operates with a general means-ends strategy, which learns.

> Whenever a production succeeds in applying an equation to derive a new known value, it creates a new production that has the previous knowns of the condition side and an assertion of the new known of the action side.... Thus, ... it becomes forward-working because all the backward-working steps become automated. (pp. 23-24).

In line with the assertion that humans behave in a similar way, it is postulated here that, as expertise develops in a particular domain, strong methods begin to dominate as weak methods decrease in use. In terms of Figure 4.1, this means that, as expertise develops, the gap or problem hurdle moves progressively towards the goal state.

In the context of train driving, drivers apply automatic procedures in dealing with routine situations such as operating the train controls, as, for example, in blowing the whistle in response to seeing a level crossing ahead. However, in train driving, as in other areas of endeavour, there are many situations which are sufficiently new or different for an appropriate action not to be immediately available from a memory search. In the event of an unsuccessful forward search, an impasse is reached, and some other way to proceed towards the goal must be found (or the goal abandoned). It is argued here that, when a search for an immediate action is not successful, there will be a switch to a weak method using backward reasoning.

In the study of a train driver described in the next section, an attempt was made to place an experienced driver in a situation that was problematic. A situation was created using a train simulator by asking the driver to drive a long, heavy train over a downward slope in unfamiliar territory. By this means, the driver's road knowledge was limited to what he could see ahead, thus limiting his forward planning. By placing the driver on an unknown track, he was deprived on some of his expertise. It was expected that this would promote backward chaining. The report of this study is then followed by a report of a study where the driver explained the actions of another driver in a train simulator. In this second study, the reasoning is also analysed in terms of forward and backward chaining.

Study of a driver driving a simulator

In this section a study of forward and backward reasoning by drivers driving a train simulator is reported. The processes are illustrated by a study of train drivers talking aloud while driving a train simulator.

Procedure and results

An experienced train driver was asked to 'think aloud' as he drove over a section of unfamiliar track using a DL2400 diesel electric simulator to simulate the driving of a long (640 metre), heavy (2,450 tonnes gross) freight train. For the run, a six kilometre section of track was selected which included a long downhill slope where heavy braking was required to keep the train from exceeding the track speed limit. The driver was given initial training on thinking aloud while driving, using another section of track. He was then asked to drive over the selected track section. This drive, with recording of protocols, was repeated three more times in the same direction. Each run took between nine and twelve minutes, with the variation due mostly to starting and stopping procedures. The fact that, initially, the track was unknown to the driver made the task somewhat problematic.

The driver's talk was tape recorded, transcribed verbatim and divided into segments of 4.5 seconds. For each run, the simulator output on twenty continuous variables every 4.5 seconds was collected electronically. The driver's talk and the simulator output were manually synchronised by time, and this synchronised data set constitutes the protocols for the study. Small segments of transcripts from the driver, coordinated with nine of the simulator variables are shown in Table 4.2 (for the first run over an unfamiliar track) and in Table 4.3 (for the fourth run over the same track).

TABLE 4.2: Backward reasoning section of protocol from the first run over an unfamiliar section of track, with simulated driving of a long, heavy freight train

Segment of Verbal Transcript	Corresponding Simulator Output									Interpretation and Explanation
	T I M E Sec	D I S T Km	L I M I T Km/H	G R A D E %	S P E E D Km/H	P O W E R Notch	A M P S Amp	A I R KPa	I N D E P KPa	
Verbatim transcript of driver's talk while driving. A slash (/) divides the transcript into 4.5 second segments which are synchronised with the simulator output.										Explanation of the drivers words (from the transcript) and actions (from the simulator output).
I'll drop it back /	360.0	3.421	80.0	-0.95	67.9	5	173	413	172	The driver realises that a speed limit of 60km/H applies to the curve ahead and so sets a goal of reducing the train speed. To reduce speed, he drops the throttle back one notch, then another. Despite this reduction, the train still exceeds the track speed limit as it comes into force.
another notch, plus another notch, due /	364.5	3.505	60.0	-0.95	64.5*	4	116	413	0	
to that 60K curve that we are negotiating - to save going around /	369.0	3.583	60.0	-0.95	61.4*	4	104	413	0	

* the train speed exceeds the track limit.

TABLE 4.3: Forward reasoning section of protocol from the fourth run over a previously unfamiliar track, with simulated driving of a long, heavy freight train and an introduced fault

Segment of Verbal Transcript	Corresponding Simulator Output									Interpretation and Explanation
Verbatim transcript of driver's talk while driving. A slash (/) divides the transcript into 4.5 second segments which are synchronised with the simulator output.	TIME Sec	DIST Km	LIMIT Km/H	GRADE %	SPEED Km/H	POWER Notch	AMPS Amp	AIR KPa	IND PIPE KPa	Explanation of the drivers words (from the transcript) and actions (from the simulator output).
Speed is increased /	274.5	1.206	80.0	-0.06	31.4	6	186	489	0	The train speed is well below the track limit and the driver increases the throttle setting to bring the speed up. The throttle is stepped up through the notches (increasing power) from setting 6 to 7 to 8. It is necessary to pause between throttle changes to allow the current amperage (load meter) to stabilise between notches.
to get the train the maximum speed. /	279.0	1.246	80.0	-0.40	32.6	6	207	489	0	
[Click] Pausing between each notch, /	283.5	1.287	80.0	-0.77	33.9	7	226	489	0	
allowing the current to rise. The locomotive now /	288.0	1.330	80.0	-0.94	35.5	8	230	489	0	
on maximum speed - maximum throttle setting /	292.5	1.376	80.0	-0.94	37.2	8	245	489	0	The throttle is now in maximum position (8th notch).
[MIN 5] to bring train up to the maximum speed /	297.0	1.423	80.0	-0.94	38.8	8	242	489	0	At the maximum throttle setting, the train speed increases to 40.5K/hr but does not yet reach the speed limit (80K/hr).
to run the time allotted by the Department for this section. /	301.5	1.472	80.0	-0.94	40.5	8	232	489	0	

Discussion of simulator study

Many segments of the protocols from the study can be interpreted in terms of forward reasoning. The protocol presented in Table 4.2 is from an experienced driver who is driving over an unfamiliar section of track for the first time. Knowledge of the track (road knowledge) is extremely important in train driving, especially under less favourable conditions such as with heavy trains, in mountainous terrain or in bad weather. Knowledge of the road ahead is important because there may be a considerable time delay between actions that a driver takes to control the speed and the response of the train to those actions. Indeed, under certain circumstances, it may not even be possible to initiate the use of the air brakes on the wagons of the train until brake pipe pressures return to normal levels after a previous brake application. To place a driver on an unfamiliar section of track is to deprive that driver of critical pieces of information that he would normally rely on in driving. In a sense, an experienced driver is stripped of some expertise when handling a train in unfamiliar territory.

The protocol segment presented in Table 4.3 is from the same driver as in Table 4.2, who is driving over the same, previously unfamiliar section of track, now for the fourth time. Within Queensland Rail, drivers are normally given three trips over a track alongside a driver who knows it well, before being asked to drive on it alone. Thus, it is likely that by the fourth time over the same track, a driver will know it reasonably well and therefore, would have gained much of the knowledge he was deprived of when faced with driving on an unknown track. Thus, it was expected that the run represented in Table 4.2 as the first drive over the track would be more problematic for the driver than that represented in Table 4.3 as the fourth drive over the same track.

The protocols from the first and fourth runs both show abundant evidence of forward reasoning characteristic of expert performance. For example, from Table 4.3, time segments 274.5 to 301.5, the driver increased speed by following a seemingly well practised routine of increasing the throttle setting from six to seven to eight notches, pausing between each movement, while monitoring the current usage from the load meter. His actions flowed smoothly forward from the initial state at the beginning of the sequence (throttle at notch six and train speed of 31.4km/H with a limit of 80km/H) until a speed of 40.5 was reached at time segment 301.5.

In the two protocols discussed here, evidence for backward reasoning is less frequent and less clear than that for forward reasoning. It is clearest in the protocol of the first run over the unknown section of track where the driver made an error of judgement which led to the train overshooting the speed limit by up to 17km/H. In the backward reasoning segment, the driver reflected on and explained this problem and his actions. The problem arose because the driver did not correctly guess the extent of the downhill grade ahead of him. A grade of -1.5 percent (i.e. the track falls one and a half metres vertically for every hundred metres travelled) is regarded as moderately steep. The slope of the relevant part of the track is between -0.90 and -1.11 for over a kilometre and could be regarded as a long, moderate descent. Without previous experience with this track, and without knowing the geography of the region, the driver had no way of predicting what lay ahead at the time he needed to take action to slow down. Because of the characteristics of the train braking systems, it was apparently not possible to slow the train quickly enough to correct the developing problem even when he understood what had happened.

In this backwards reasoning section, the driver is reflecting on an unsafe situation where the train picked up speed rapidly and exceeded the speed limit by a considerable margin. In segments 360.0 to 369.0, presented in Table 4.2, the driver says, 'I'll drop it back another notch, plus another notch, due to that 60K curve that we are negotiating — to save going around...'. The driver realises that a speed limit of 60km/H applies to the curve ahead (he may have been able to see the speed limit sign board) and so sets a goal of reducing the train speed. To reduce speed, he drops the throttle back one notch, then another. This is backward reasoning because the driver works back from the goal (slowing down) towards the actions that must be taken (reducing throttle). In other words, the reasoning is goal-based rather knowledge-based (Hunt, 1989; Patel & Groen, 1991).

Despite this reduction in throttle, the train still exceeds the speed limit when it comes into force. The driver had an alternative way of slowing the train by using the brakes. Had he known that the track continues on a sharp descent (a grade of -0.95) through the curve, he may have taken this way of reducing the speed more sharply, as indeed he did at this point in the fourth run over the same track.

In conclusion, there is some evidence of backward chaining in the seemingly problematic situation created on the simulator. However, the instances identified in the verbal protocol are few and evidence of backward chaining scant. One explanation is that the situation was not as problematic as it appeared. Another is that verbal protocols, relying as they do on the verbalisation of propositional knowledge, do not adequately capture the procedural components of problem solving in train driving. To explore these possibilities further, a second study of train drivers, involving verbal problem-solving in diagnosing a problem in train driving, was undertaken. It was hoped that, in this second study, because the driver could devote all of his attention to diagnosing and explaining the actions of problem-solving, a deeper analysis would be possible.

Study of train drivers performing a diagnostic task

In the first study reported above, a verbal protocol from a driver driving a train simulator was recorded and synchronised with graphical and numerical output from the simulator. This driver was asked to drive over a steep, unknown section of track. The task proved to be a difficult one, with the driver exceeding the speed limit by a considerable margin. In this second study, a section of the earlier protocol was shown to another driver who was then asked to diagnose the performance of the driver from the earlier study. This section reports on the analysis of the verbal protocol derived from this diagnostic task.

The diagnostic protocol was gathered by asking the subject of the study to explain a short segment of the driving as represented by graphical and numerical output from a train simulator synchronised with verbal protocol. The stimulus material was essentially propositional in form. The diagnostic protocol was tape-recorded, transcribed verbatim, segmented into short lines at clause or phrase boundaries, and coded. The coded protocol, consisting of 332 numbered lines, is appended. The task for the study asked the subject to explain his thinking, and the outputs from these explanations were captured in the protocol. For this task, the stimulus and the response are essentially propositional. The procedures involved in explaining are processes which manipulate propositional knowledge components. Thus, in

contrast to the task used for the simulator study reported earlier, the diagnostic task is centred on the input, processing and output of propositional knowledge.

Coding scheme

Based upon the work of Groen and Patel (1988, 1991) and Patel and Groen (1991) on forward and backward reasoning (See Table 4.1) and the conceptualisation of forward and backward links depicted earlier (See Figure 4.2), operational definitions and codes for elements of forward and backward chaining were formulated as shown in Table 4.4. Operational definitions and codes were also formulated for the three backward and four forward categories identified by Groen and Patel and are shown in Table 4.5. However, many more types are possible. For example, it is theoretically possible that any of the three elements in the left hand (antecedent) column of Figure 4.2 may be linked to any of the five elements of the right hand (consequence) column by either forward or backward connections. Therefore, there are fifteen possible forward and fifteen backward categories. Thus, this schema simplifies the work of Groen and Patel in that it establishes a general pattern for any episode of forward or backward reasoning; and extends the range of possible categories. The general pattern involves two elements joined by a directional link. One of the elements in this pattern must be an antecedent and the other a consequence element (See Figure 4.2). If the antecedent occurs before the consequence, the chaining is in the forward direction; otherwise it is a backward link.

In the process of coding the protocol (as described in the next section), all of Groen and Patel's categories listed in Table 4.5 were identified, as well as many of the additional hypothesised categories. Also, three other variations on the hypothesised coding scheme were found and the scheme modified to accommodate these variations. These variations involved overlapping episodes, combining like elements within an episode and embedding of episodes within other episodes. This expanded conceptualisation of forward and backward chaining and the codes devised were applied to the diagnostic protocol as described in the next section.

TABLE 4.4: Element codes used in the coding scheme

Code	Operational Definition by Present Author
Antecedent	
fac	Fact — a statement which has been given or previously derived during the course of reasoning about the situation or recalled from a similar situation; an observation made about the situation or information given
pat	Pattern — an arrangement of given information which is recognised by the subject and leads directly to an action, inference or solution
cnd	Condition — the circumstances under which some linked action will take place or under which some linked fact will be true
Consequence	
act	Action — an operation which will be executed when certain conditions are met; a procedure that is carried out
gol	Goal — a statement of what is or was desired; a question to which an answer is sought
hyp	Hypothesis — a guess at a solution or partial solution; a guess at what actually took place
new	New Fact — a newly deduced fact; information derived from a previously known fact; an inference which is accepted as true by the subject; an inference under a hypothetical scenario, which is regarded as true under the scenario
sol	Solution — a resolution or conclusion about the whole situation or about that part of it under consideration; hypothetical solution or partial solution derived from a postulated scenario

Coding the protocol

In coding the diagnostic protocol, both elements and episodes were coded to yield a dual coding scheme. Elements were coded using the lower case codes and operational definitions in Table 4.4. For example, line 131 'Then once you've got that' is coded as a condition (cnd) and line 132 'let her down' is coded as an action (act). An episode was defined as a set of semantically related elements based on the pattern of element-link-element as described in the previous section. Episodes were coded with an upper case code consisting of F or B (for forward or backward) followed by the initial letters of the elements forming the episode. Thus, FCA is a forward

TABLE 4.5: Codes and operational definitions of forward and backward categories

Element Linkages	Code	Operational Definition
Backward Categories		
a hypothesis linked back to a fact	BHF	a hypothesis or guess is compared with the facts of the situation
a goal linked back to a fact	BGF	links are made from a goal to join in known facts
a solution linked back to a fact	BSF	facts are sought in order to link them into a developing solution or explanation (which is growing back from the solution)
Forward Categories		
a fact linked forward to a goal or solution	FFG	facts or given information are used to make links towards the solution or goal
a fact linked forward to a new fact	FFN	a deduction or connection is made from a given or deduced fact towards a new fact that has not been given or deduced previously
a pattern used to link forward	FPS	a pattern is recognised, then used to reach a solution
a condition (of a rule) linked forward to the action (of that rule)	FCA	when the conditions are met, the linked actions of the condition-action production rule will be executed

episode consisting of a condition and an action. To form a complete episode, one antecedent element must be linked to one consequence element in either a forward (antecedent→consequence) or a backward (consequence→antecedent) direction.

The process of coding was to look for expected patterns and for variations on these simple patterns. For the most part, elements were simple sentences or clauses uttered by the subject, but there was sometimes elaboration, repetition or restatement to yield a clause complex which was

coded as a single element. For example, lines 020-022 involve a qualifier 'It look's as though' to the main clause 'he's just kept going' which is itself elaborated, 'waiting for it to sort itself out.' In this case the qualifier signals the tentative nature of the statement to follow and so the qualifier, the main clause and the elaboration are coded as one element, and this element is classified as a hypothesis (hyp). Using such contextual and syntactic clues, almost every clause or clause complex uttered by the subject could be classified using the lower case element codes. There were only two exceptions — at lines 43 and 94 where the subject's sentences were too incomplete to code. However, there were many ambiguities where more than one code could be applied.

The complementary coding scheme allowed a degree of cross checking between the two types of codes and hence improved reliability and validity. For example, the occurrence of two antecedent or two consequence codes in succession invoked special attention. The only way in which one of the lower case antecedent elements (left hand column of Figure 4.2) can immediately follow another antecedent element is if one episode (upper case code) is embedded in another, for example, as shown in Table 4.6.

TABLE 4.6: Embedded episode from the diagnostic protocol

Line	Protocol Segment	Element *	Episode
174	So, he's asking for trouble,	] hyp	]
175	isn't he?		|
176	(Right)		| BHF
177	If he can't, (control speed)	) cnd	]
178	he's lost his job.	) new	] FCN
179	I was just thinking what I did, you know.	) fac	]

* Hypothesis (hyp) and condition (cnd) are antecedent elements; new fact (new) and fact (fac) are consequence elements.

To resolve ambiguities, only those element codes which were consistent with complementary episode codes were accepted. The complete coded protocol is appended, with vertical bars marking the boundaries of episodes. Table 4.7 shows the number of each type of episode found. All three types of the backward episodes (BHF, BGF and BSF) and all four types of forward episode (FPG, FFN, FPS and FCA) derived from Groen

and Patel's work were found in the protocol. In all, fifteen of the thirty theorised categories were found. Of the 65 episodes coded, 38 were categorised as 'forward' and 27 as 'backward'. Figure 4.4 shows the distribution of forward and backward episodes along a time line from beginning to end of the protocol.

TABLE 4.7: Number of each type of episode in the diagnostic protocol

	Antecedent								
	Fact		Pattern		Condition		Total		
	For	Back	For	Back	For	Back	For	Back	Both
Consequence									
Hypothesis	0	* 13	0	0	0	0	0	13	13
Goal	* 2	* 9	0	0	1	0	3	9	12
New Fact	* 3	0	0	0	2	0	5	0	5
Solution	8	* 1	* 5	0	6	1	19	2	21
Action	1	1	0	0	* 10	2	11	3	14
Total	14	24	5	0	19	3	38	27	65

Note 1: * = derived from the work of Groen & Patel and Patel & Groen.
Note 2: 15 of the 30 theorised types of episodes (6 backward and 9 forward) were found.

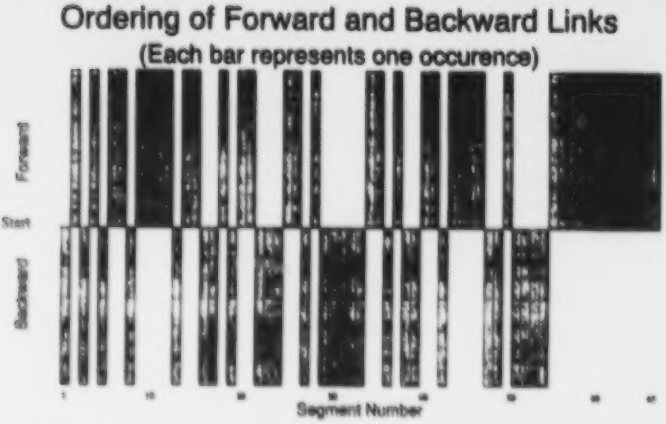


Figure 4.4 Distribution of forward and backward episodes from the diagnostic protocol

Discussion of the diagnostic study

The analysis as summarised in Figure 4.4 shows abundant evidence of backward chaining for the diagnostic study. This is in contrast to the evidence from the simulator study reported earlier. One explanation is that the diagnostic task is, in fact, more problematic than the simulator driving task and that backward reasoning is associated with problem solving. An alternative explanation is that, because the diagnostic task of the study focused on the acquisition and manipulation of propositional knowledge, that the verbal protocols more adequately captured the backward chaining of the processes involved. Further research is needed to elucidate differences between different kinds of problem solving tasks.

Despite the questions raised by the differences between the two studies, it is clear from Figure 4.4 from the diagnostic study that switching between forward and backward reasoning occurs frequently during problem solving that is centred on propositional knowledge. Figure 4.4 also reveals that the distribution of this switching is not uniform and that the last 12 of the 65 episodes are all in the forward direction. These last 12 episodes seem to

reach closure on the problem posed in the task by reiterating an explanation (i.e. a solution to the problem) that was progressively derived earlier in the protocol.

The interpretation of the data is that, when faced with a problem of this type, switching between forward and backward chaining occurs until a complete explanation is derived. Once assembled, the completed chain can be 'explained' in a forward direction from initial to goal state. In terms of Figure 4.1, this means that, early in the task, the subject is trying to find a path from the initial state by progressively chaining links in a forward direction where the links are available. Where links are not available, the subject switches to backward chaining, trying to complete the chain from the goal state back towards the initial state. Switching continues until the problem hurdle is bridged by the joining of a forward and a backward chain to form a complete chain. The complete solution can then be recited in a forward direction from the initial state to reach the goal. Thus, it is argued, that, through backward chaining, longer forward chains are composed and these chains can be 'read' or executed in a forward direction.

In terms of Figure 4.3, the links being made at the procedural level are reflected at the conceptual level and by vertical links, which form cylinders between the planes. As outlined earlier, cylinders represent associations between conceptual and procedural knowledge and connections to the functional context. A growth in the number of cylinders which results from lengthening of the connected chains is therefore a growth in expertise in terms of Stevenson's definition (Chapter 1).

This explanation provides a mechanism for phenomena noted by other researchers. For example, Jansweijer, Elshout and Wielinga (1990) have noted repair-impasse cycles in novices working on thermodynamics problems:

> We conclude that a novice in a learning by doing session typically progresses slowly through many cycles of thinking what to do, failure in doing it, followed by a reasoned attempt to repair the plan so that its execution may continue. The novices in thermodynamics that we studied, in only 9% of the cases reached the correct answer, without having gone through several impasse-repair cycles. Our position then is that a theory

> of learning to solve problems by doing rests incomplete as long as it does not also give an account of the remarkable ability of novices to carry on, not coming to a griding halt whenever the knowledge base proves imperfect. (p. 132).

The results from the diagnostic study indicate that asking learners to explain problem situations presses them into using backward reasoning. Backward reasoning appears to be an important component of problem solving centred on conceptual knowledge. However, this research raises the question of whether backward reasoning is applicable in situations which are highly procedural and further research is needed in this area.

Teaching strategies and learning outcomes

While many ways have been developed for teaching information such as facts, concepts, principles and theories (propositional knowledge), there has been far less attention given to the teaching of routine skills and even less to the development of higher order skills, especially in vocational education and training. Yet it is these higher order skills which seems to be involved in the ability to transfer learning from one setting to another, the ability to juggle competing demands and the ability to monitor and evaluate performance effectively.

Stevenson (1991) argues in line with Posner (1982), that learners deal with learning tasks by employing those cognitive structures they perceive to be relevant. Thus, the role of the instructor in developing expertise and adaptability is to create a learning environment which encourages learners to use higher order procedures. Stevenson (1986a, b) advocates environments which are open and problem-centred and where knowledge and action are elicited from students. In a similar vein, Evans (1991) advocates learning environments in which students are actively encouraged to set their own goals and to discover strategies for themselves. Train simulators which can be used to create controlled, problematic situations for driver investigation, discussion and elicitation are therefore invaluable tools in helping to construct open, problematic learning environments.

Research into vocational skill development has suggested that training environments can be constructed that promote the development of either specific or higher order skills. For example, Stevenson and Evans (in press) and Stevenson, McKavanagh and Evans (Chapter 7) advocate that to develop routine skills, it may be adequate to use strategies where trainees are encouraged to copy the teacher, follow instructions, rely on the teacher for new ideas and procedures, execute plans provided by the teacher, rely on the teacher for links and for checking on the results, passively accept new information and procedures and accept results of activities. On the other hand, to develop higher order skills which lead to adaptability in the face of change, trainees need to be pressed into interpreting new situations, making plans, solving new problems, making links between existing and new knowledge, generating ideas, trying out new ideas and procedures, checking the results of new procedures against existing knowledge and monitoring their own activities. From the results of the diagnostic study reported here, explaining the actions of others can be added to this list.

Conclusion

It is argued here that, to develop expertise which leads to adaptability, training situations need to be provided which encourage the development of backward chaining in a functional context. Through this means, better developed forward chaining is assembled, as well as richer links between concepts and procedures and the functional context. However, our knowledge of these phenomena are incomplete and further research is needed.

If training courses are to develop adaptability in train drivers, then they should develop higher order skills. This means that courses need to be redesigned and training scenarios created especially to promote these skills. Simulators should be an integral part of the instructional design and delivery process because simulators make it possible to reproduce, modify and control scenarios at will and to interact with these. They provide for experimentation, feedback and reflective possibilities at a level that is not possible using real trains. In other words, simulators enable instructors to create the kind of innovative learning environments that promote higher order skills. There are many challenges in designing courses which incorporate these features.

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Appendix — Coded protocol

001 {Tape 7, Side B. Experimenter's comments added during [
002 transcription are enclosed in braces. Experimenter's comments [
003 recorded with the protocol are enclosed in parenthesis} [
004 {Diagnostic Protocol — Rockhampton, 5M93} [
005 {*Line numbers* added during coding are at left margin. [
006 Codes with line references are at right margin. [
007 Experimenter's explanations Start at Tape Count 228 [
008 This driver has driven over [
009 a previously unknown section of track [
010 four times, using the simulator. [
011 He is now presented with a protocol [
012 from another driver also driving [
013 over the same section of track. [
014 Summary graphical output [
015 and numerical simulator output [
016 for this previous driver is also [
017 presented and explained.} [
018 {Driver talk starts at about Tape Count 242} [
019 {Tape Count 259} (What do you think he has done?) [
020 ┌ Well, it look's as though [BHF–024[hyp–022
021 | he's just kept going — [
022 | waiting for it to sort itself out. [
023 | And it just didn't. [fac–024
024 └ It just got worse. [
025 ┌ And as it got worse, [FCA–029[cnd–025
026 | he just reduced, {power} [act–029
027 | he's reduced his power again. [
028 | He just keeps reducing, {power} [
029 └ he gradually reduced..., {power} [
030 ┌ he still kept air... [BHF–034[hyp–030
031 | ┌ he's released it here. [fac–034[FFN–035
032 | | See, it's gone back up to 455, eh. [
033 | | It's up to 475. [
034 └ | It's coming back {i.e. charging up}. [
035 └ so he's released his brakes. [new–035
036 ┌ And what speed's he doing? [BGF–039[gol–036
037 | Now, here 60. [fac–039
038 | (Ah, 60 is the limit. [
039 └ His actual speed is 59.) [

040 ┌ So therefore, that's ah, ah, ah. [FFN–042[fac–040
041 | that's his release. [new–042
042 └ He's released it up. [
043 | Yeah, where's your — [xxx–043
044 ┌ 51, 50. 50.4 [FFN–045[fac–044
045 └ he released it. Oh, yeah. [new–045
046 ┌ Well I would've too in that situation. [BHF–049[hyp–046
047 | Well I think I did as a matter of fact — [AND[hyp–047
048 | that first one [fac–049[
049 └ (first run over unknown track?). [
050 ┌ I did. [FPS–053[pat–051
051 | I pulled it back to 50 and let her go. [
052 | (Right) [
053 └ That's what I did too. [sol–053
054 ┌ I'd normally. [FPS–060[pat–057
055 | Under normal that — [
056 | giving yourself [
057 | a 10 km/hr leeway on this (??) [
058 | (Right) — [
059 | and that should give you [sol–60
060 └ enough time to get a recharge. [
061 (Yes, okay) [
062 ┌ In my case it didn't. [FPS–063[pat–062
063 └┌ And neither did it for him. [sol–063[FFS–066[fac–063
064 |Thank God. [sol–066
065 |I'm glad [
066 |there's two of us in this boat. [
067 (Laughter from both) [
068 (You were lead into it.) [
069 ┌ Yeah, if this (stimulus protocol) [BHF–071[hyp–070
070 | is not mine — [
071 └┌ I don t think I went that high. [fac–071[FFS–072
072 |so it can't be mine — [sol–072
073 (No) [
074 ┌ ah, 'cause, [FCG–077[cnd–075
075 | as soon as he got back up to here, [
076 |┌ he should have grabbed her again [gol–077[BGF–078
077 └|(i.e. braked). [
078 └ He hadn't got it and neither was mine. [fac–078
079 (Um) [

080	┌ He should have grabbed it —	[BGF–084[gol–080
081	└ ┌ you've still got enough air	[fac–084[FFS–085
082	| to pull your train in —	[
083	| that's cycle braking. Right?	[
084	| (Right)	[
085	└ But you can still grab it.	[sol–085
086	┌ He appears to me — ah,	[BHF–100[hyp–088
087	| I suppose he'd have peed himself.	[
088	| poor bugger...	[
089	| He's just sat there,	[AND[hyp–090
090	| ignored his speed,	[
091	| and let his air come back up.	[AND[hyp–093
092	| He waited for his air,	[
093	| to recharge his train	[
094	| before he would — you can't —	[xxx–094
095	| (That's what he's saying here	[
096	| {stimulus protocol} isn't it?)	[
097	| Yeah,	[fac–100
098	| 'Brake wasn't charged up	[
099	| to enable me to make'	[
100	\└ {quote from stimulus protocol},	[
101	┌ but you can make	[FFA–120[fac–102
102	| a further brake application.	[
103	| ┌ Well, as soon as	[FCN–105[end–104
104	| | the flow meter starts to flow,	[
105	| \└ you've got air that'll pull you up.	[new–105
106	| ┌ What you've got to do,	[BGF–115[gol–111
107	| | well I believe anyway,	[
108	| | you can't,	[
109	| | you just can't let your speed	[
110	| | to go up around a 60K curve	[
111	| | on a big train like that.	[
112	| | You've got to keep your speed down —	[AND[gol–113
113	| | that's safe.	[
114	| | So, you know you've got enough air	[fac–115
115	| | to pull it up anyway.	[
116	| ┌ So alright pull'er up.	[BGF–117[gol–116
117	| \└ Use your brake,	[fac–117
118	| but make sure you use	[act–119
119	| a heavier brake —	[
120	\└ let it settle —	[AND[act–120

121	put your brake on.	[BAF–125[act–121
122	let it settle down.	[AND[act–122
123	then give'er a bit more and, and,	[AND[act–123
124	and it's got to be a larger reduction	[fac–125[FFS–129
125	than you made the first time.	[
126	(Right. Okay)	[
127	To make sure you've got that over,	[sol–129
128	over the, to overcome the,	[
129	to make sure your brakes'll come on	[
130	(Right)	[
131	Then once you've got that,	[FCA–132[end–131
132	let her down,	[act–132
133	but this time	[BGF–135[gol–134
134	don't let it catch you again.	[
135	Which I didn't either	[fac–135
136	from what I did,	[FPS–141[fac–137
137	I pulled her right dow,[	[AND[fac–140
138	and making sure,	[
139	that when I did release it,	[
140	the air,	[
141	I would have air for the next time.	[sol–141
142	But he's ignored his speed	[BHF–144[hyp–142
143	and gone for air.	[AND[hyp–143
144	But you've got air —	[fac–144
145	you'll get your air back	[BHF–146[hyp–145
146	if you pull your speed down.	[fac–146
147	(Okay)	[
148	The trick is though,	[BGF–153[gol–149
149	to bring it down,	[
150	to make sure its low enough	[AND[gol–150
151	that you've got a full head of air	[AND[gol–152
152	the next time and that release.	[
153	Even if it means stopping.	[fac–153

154	(Right. So, where has he made	[
155	his biggest mistake in that?)	[
156	┌ He's ignored his speed.	[BHF–161[hyp–158
157	| It's just that he's forsaken speed	[
158	| to get air.	[
159	| (Right. Okay)	[
160	| But that's	[fac–161
161	└ just as dangerous a situation.	[
162	(Right)	[
163	┌ I, I, I believe, anyway,	[BHF–167[hyp–165
164	| I think the safest way	[
165	| would have been to — {stop}	[
166	| you've got enough air	[fac–167
167	└ to pull your train up,	[
168	┌ even though your brake pipe's	[FCA–171[cnd–169
169	| not fully recharged —	[
170	└ pull the — {speed down}	[act–170
171	┌ even if it means stopping,	[FCS–173[cnd–171
172	| but don't exceed the track limit	[aol–173
173	└ on a 60K curve.	[
174	┌ So, he's asking for trouble,	[BHF–179[hyp–175
175	| isn't he?	[
176	| (Right)	[
177	| ┌ If he can't, {control speed}	[FCN–178[cnd–177
178	| └ he's lost his job.	[new–178
179	└ I was just thinking what I did, you know.	[fac–179
180	(Right)	[
181	┌ That's his job {gone}	[BSC–183[aol–187
182	| if he comes off the road	[cnd–183
183	└ at that speed.	[
184	(Right. Um. Maybe)	[
185	┌ But, well, that's what I was saying,	[BSF–187[aol–187
186	| but it doesn't matter,	[
187	└ the speed is the thing	[fac–187
188	┌ even though this was a track	[FCA–190[cnd–189
189	| I didn't know,	[
190	└ that's what I'd do myself.	[act–190

151

191	Even though I didn't know	[FCA–195[cnd–192
192	what was coming up after me.	[
193	Each time I hit the brake	[act–195[BAC–197
194	on that first one {run},	[
195	I still pulled her down,	[
196	because I didn't know	[cnd–197
197	what was coming up.	[
198	And when you don't know	[FCA–205[cnd–199
199	what's coming up,	[
200	you've got to play on the safer side.	[act–205
201	(Right)	[
202	And that means pulling your speed	[
203	right down.	[
204	(Okay)	[
205	and holding it,	[
206	if it means stopping.	[FCS–207[cnd–206
207	'cause that'll get you out. {of trouble}	[sol–207
208	The second I let her go the next time	[FCA–209[cnd–208
209	I'll stop'er.	[act–209
210	I'm going to pull'er down {brake}	[FPS–228[pat–211
211	until I do get the air back.	[
212	You don't achieve the speed.	[BGF–218[gol–215
213	You must keep the speed down.	[
214	It's top priority	[
215	to keep that speed down.	[
216	(Right)	[
217	And the only way you're going to do	[fac–218
218	that is with brakes.	[
219	So, and to keep that braking power,	[BGF–221[gol–219
220	you've just got to keep pulling right back	[fac–221
221	before you release,	[
222	even if it means stopping	[FCS–223[cnd–222
223	and getting it back.	[sol–223
224	(Right)	[
225	Have your independent hold her	[BAC–226[act–225
226	while it pumps up.	[cnd–226
227	(Okay)	[
228	That's what I do anyway.	[sol–228
229	{Laughs}	[
230	You've got me carried away now.	[
231	{Laughs}	[

232 (Well I wanted to show you [
233 that you weren't the only one [
234 who was led into the situation.) [
235 Yeahh. No, I, I know, [BHF–246
236 I just, I would know, no, [
237 I'd have been getting a bit toey [hyp–238
238 at that speed. [
239 I just — [
240 (He was very anxious) [
241 I bet he was (anxious). [
242 'Cause you just know [fac–246
243 in your own mind, [
244 it's too fast [
245 for what, for the road [
246 you're going over. [
247 But he just, but, what he, [BHF–253[hyp–252
248 for what I can see, [
249 he just sat there [
250 and said, 'Well I accept it', [
251 even though he didn't like it. [
252 He accepted it to get air. [
253 But he didn't have to. [fac–253
254 (Right. Okay) [
255 Well I don't think he did. [BHF–259[hyp–256
256 I don't think he had to. [
257 All he had to do was [fac–259
258 give it an application, [
259 make it a greater one [
260 after it'd settled, [FCA–261[cnd–260
261 make it a greater one. [act–261
262 Pull his train right down. [FCS–264[cnd–262
263 (Right) [
264 He's got his train back under control. [sol–264
265 (Okay) [
266 And he, [FCA–270[cnd–269
267 once he's pulled her right down [
268 to the low, very low, [
269 even, if as I said it means stopping. [
270 Release her. [act–270

271 ┌ And he didn't do that. [FCS–273[cnd–271
272 | And he hasn't exceeded the speed [sol–272
273 └ and he's still got his job. [AND[sol–273
274 (Laughs) [
275 ┌ And you'll throw the timetable [FFG–283[fac–276
276 | out the window. [
277 | (Right) [
278 | Never, I never worry [gol–281
279 | about sectional times. [
280 | Never. Never worry [
281 | about sectional times. [
282 | (Right) [
283 └ Always make sure, or try to — (arrive on time) [BUT[gol–283
284 ┌ not that you don't [FFS–290[fac–286
285 | exceed the speed, [
286 | of course, we all do, [
287 | well you misjudge — [sol–290
288 | it's all judgement, [
289 | that's what it is. [
290 └ It's all judgement. [
291 ┌ When you've got to make that — [FFS–306[fac–302
292 | you can image the number of decisions [
293 | you've got to make — [
294 | the judgements you've got [
295 | to make just in one trip. [
296 | (I...) [
297 | This is on all the time. [
298 | (I'm beginning to realise, yes) [
299 | These judgements are on [
300 | every time we touch [
301 | a throttle or a brake. [
302 | We're making these judgements. [
303 | And, that's what you've got to do. [sol–306
304 | Naturally, [
305 | all those decisions [
306 └ you've got to make. [

307 ┌ As I said, you've to make, (judgements) [FFS–328[fac–302
308 | ┌you don't even have to be a bit tired. [FCS–315[end–311
309 | | This day you can come in, [IOR[end–310
310 | | fresh as a daisy, talking football, [
311 | | or, you know, [IOR[end–312
312 | | something distracts you. [
313 | | (Yeah) [
314 | | As long as you don't miss by too much [sol–315
315 | └is the main thing. [
316 | (Laughs) [
317 | (Okay) [
318 | ┌And then, as I said to you before [FFG–321[fac–319
319 | | that, you can do that, pull it down, [
320 | | do what you believe [gol–321
321 | └is the right thing. [
322 | ┌get your speed right down. [FCA–323[end–322
323 | └let her go, [act–323
324 | ┌and out walks a navvy with a red flag [FFS–326[fac–324
325 | | (Right. Upsets all your plans) [
326 | └Blows the lot (plans) out the window. [sol–326
327 | (Right) [
328 └ Ah, that's when you panic. [sol–328
329 (Laughs) [
330 (293 We have to go and catch a plane [
331 back to Brisbane) [
332 (294 End of tape) [

5 Problem-based learning in workshops

Howard Middleton, Griffith University

Abstract *Innovation and creativity are increasingly seen as important elements of workplace expertise. In this chapter the nature of creativity is examined. An argument is presented that the development of creative thinking abilities is necessary for vocational students to respond adequately to complexity and change in workplace settings. Problem-based learning is conceptualised as learning where the learner is 'pressed' into engaging in creative activities. An important outcome of problem-based learning is an increased ability to think creatively.*

The results of a study of teaching and learning in workshop classes is reported. The Torrance Test of Creative Thinking Abilities was used. On the basis of the results it is concluded that creative thinking abilities can be developed with appropriate learning tasks and settings.

The implications of these results are examined and suggestions made about the development of the creative thinking abilities of vocational education students. Current research suggests that creativity is an inadequately developed ability in vocational education students. In addition to the development of the ability to address routine tasks (near transfer) and tasks that are unfamiliar (far transfer) vocational students need to develop the ability to come up with new and worthwhile responses to problems encountered in conditions of change and complexity. Issues concerned with competency based training and creativity are also discussed.

Introduction

Reference to the changed nature of work is made in Chapter 1. Laur-Ernst (1992) indicates that workplace demands over the last decade have changed substantially and that individuals need to be able to handle complex, indeterminate situations where no rules apply and need to use imagination, improvisation and creativity in solving problems.

The argument is also developed in Chapter 1, that technical expertise involves the ability to do more than perform routine technical tasks. Technical expertise requires (among other abilities) the ability to generate and evaluate skilled performance as technical tasks become complex and as situations and processes change. Here it is argued that technical expertise also involves the ability to innovate.

That is, it is argued in this chapter that expertise involves being able to respond to change where new responses are required. These responses will be new not only to the individual worker, but new in terms of the accumulated procedural knowledge held within a work setting.

Mention is made in Chapter 6 of the need for the graduates of vocational education to be adaptable and to be able to engage in complex problem-solving. Here it is argued that, with changing environments in industry it may be equally important to be able to anticipate change and, on the basis of the anticipation, to initiate change. This could be at the level of problem-finding, and/or as a developed attitude, that is, having the attitude that particular procedures are capable of being changed and improved and that such changes are a normal part of the working environment. Being aware of this, expert workers may devise better ways to do things, or, in changed situations, be able to see possibilities for actions that do not currently exist.

In the following sections, the argument is developed that creativity is a universal attribute that can be developed with appropriate learning experiences.

Complex problems

Vocational education students need to be involved in solving complex problems if they are to be prepared for a work environment characterised by change and uncertainty. What then, are complex problems? Problems can be complex because they are ill-defined. Problems are ill-defined when they:

- contain a vague or ambiguous problem statement. For example, in architecture, a client will specify some of the properties of a

building to be designed, but the architect will need to supply many more details before the problem can be solved;

- have no known solution path. For example, when existing methods for solving particular problems are no longer possible, new solution paths must be created and being new, are not known at the outset of the problem-solving process;

- have vague goal criteria, that is, if a problem is new and, therefore, has never been solved before, it may not be possible to specify in advance what the precise solution criteria can be. For example, when using a new material in the solution of a problem it may be necessary to establish by trial and error, the limits of the new material's utility in the problem solution and in so doing, establish more precise goal criteria.

Problems, then, can be complex because they are ill-defined: they can have an ambiguous problem statement, an unknown solution path and vague goal criteria. It is argued that such problems require creative thinking processes to achieve resolution. In the following paragraphs, the nature of creativity and problem-based learning are discussed; and an empirical study of the utility of problem-based learning in developing creativity is reported.

Creativity

In this section, the nature of creativity, its relationship with intelligence, stages in creative thinking and measures of creativity are outlined. Creativity research has concentrated on two manifestations of creativity. One area of research has been concerned with the nature of creativity manifested by highly creative people such as Einstein, Poincare, Kekule and Edison, to name a few. The second area is concerned with examining creativity as a universal attribute which Maslow (1962) termed self actualising creativity. Self actualising creativity has a functional role in problem-based learning as it is deemed to be an ability that all people possess (in varying degrees) and an ability that can be developed through learning.

A number of studies has suggested that creativity may be simply a manifestation of intelligence. Studies by Roe (1953) and McKinnon (1968) found that highly creative individuals had higher than average intelligence; however, Hayes (1989) argues that creativity and intelligence are independent abilities. The apparent correlation between intelligence and creativity can be explained, according to Hayes (1989), as a function of the selection of occupations for creativity research. Indeed, most studies in creativity have been conducted with occupations that employ university graduates, such as scientists and architects. The scores for intelligence may be related more to success in meeting the academic requirements of university study, than having any causal relationship with creativity. An informal assessment of correlation between scores on the Torrance Test and school measures of intelligence for the problem-based learning group (Group B), reported in this chapter (see below), was made. This informal assessment supported Haye's (1989) contention that intelligence and creativity are independent.

In describing creativity, a four stage process originally formulated by Wallas (1926) is employed. The stages are preparation, incubation, illumination and verification. The four stages are not discrete but overlap. In addition, the process of creative thought is not uniformly forward working, but can move backwards, for example, from illumination to preparation, or verification to incubation. The awareness of the solution to one aspect of a problem may reveal another problem for which there is insufficient knowledge or understanding for the problem-solver to solve.

Preparation is an important element of creative thinking (Wallas, 1926; Hayes, 1989). Preparation involves developing a deep conceptual understanding of all aspects of the problem situation. Preparation involves acquiring knowledge of how to do things (procedural knowledge) and knowledge of facts that might be useful in solving a problem (declarative knowledge). Preparation is a prerequisite to creative thinking but does not guarantee that creative thinking will occur.

The manner in which a problem is represented can significantly affect the chances of a problem being resolved. The initial representation of a problem is part of the preparation stage. Kotovsky, Hayes and Simon (1985) demonstrated that a problem, represented one way, could be sixteen times as hard to solve as the same problem represented in another way. In

a more recent study, Antonietti (1991) demonstrated that with some problems, visual mental images provided better representations than verbal representations. Hayes (1989) has argued that finding the best problem representation, which Hayes describes as goal setting, is the most critical element in creative problem-solving.

Problem representations are a product of problem-finding. Problem-finding is the activity of searching for the best way to represent a problem. People good at problem-finding are also able to change direction during the problem-solving process to take account of changes that may occur. In a longitudinal study of tertiary art students and their subsequent careers, Getzels and Csikszentmihalyi (1976) found that students who engaged in extensive problem-finding were more successful in careers where developed creative abilities are regarded as important.

A related study concerned with idea generation techniques (Kaufmann, 1981) provided support for the importance of problem-finding in creative problem-solving. Kaufmann (1981) reported that people's initial representations of problems were generally uncreative, while ideas produced later in the idea generation experiment were notably more creative.

After preparation, Wallas (1926) argues that a process of incubation occurs. Incubation is a significant process in solving complex problems but is an aspect of creative thinking that has been difficult to capture in research (Gilhooley, 1982). Incubation is assumed to be a preconscious or unconscious process that occurs while the thinker has broken off conscious thought of the problem and is engaged in other activities. As a consequence, researchers have had difficulty establishing that incubation is occurring at any particular point in the creative thinking process (see Ericsson & Simon, 1984). Introspective reports from creative scientists, however, attest to the existence and value of incubation (Gilhooley, 1982). It is likely that incubation is an important element of creative thinking only when the problem-solver is engaged in solving problems that are complex and effortful for the problem-solver.

Incubation is the equivalent of what Simon (1969) describes as 'selective forgetting'. In selective forgetting, the mind, when not attending to a problem, allows the representation of the problem to return to long-term

memory. When the representation is retrieved from long-term memory, unsuitable elements of the representation have been forgotten, thus producing a better problem representation. The process by which elements are selectively forgotten and remembered has not yet been resolved.

Illumination is taken to be the point at which a synthesis occurs and disparate elements of a problem come together to provide a new solution (Gilhooley, 1982). There is some debate as to whether illumination is an instantaneous event or a gradual synthesis. At any rate, an explanation of the cognitive processes involved in the illumination stage of creative problem solving has, as yet, not been found. In Simon's (1969) theory, illumination could be said to be the final product of the unconscious, selective forgetting that gradually removes all unsuitable problem elements until the representation that comes to consciousness is the problem solution.

Recent research investigating the role of imagery in creative visual synthesis has demonstrated that people are able to use visual imagery to produce new ideas (Finke & Slayton, 1988). In a controlled experiment, people were shown drawings of three randomly selected simple shapes such as squares, triangles and alpha-numeric symbols. People were instructed to close their eyes and see if they could combine the shapes to produce an identifiable object. Objects produced were then named, and sketches made of them.

An expert panel then made judgements, firstly, as to the fit between object label and sketch, and then to determine if any objects were notably creative. Control measures were taken to rule out the possibility that the objects produced were simply the result of predictions people could make on seeing the shapes. A significant number of identifiable objects was produced and a significant number of these identifiable objects was judged to be notably creative. The experiment is taken as demonstrating that people can produce creative visual syntheses. Illumination could be said to be the point at which the new shape emerges and is recognised.

Verification, also described as revision (Hayes, 1989; Hayes, Flower, Schriver, Stratman, & Carey, 1987), is the conscious process of filling in the details of the generalised concept produced during illumination. Verification also embodies an evaluation function in Hayes' (1989) revision process. Expertise in creative problem-solving involves the ability to assess

the shortcomings of one's own work accurately (Hayes, 1989; Hayes, et al, 1987).

Expertise in solving complex problems that require a creative solution then, is a product of good preparation, choosing good ways to represent a problem, such as with mental imagery, using appropriate idea generation strategies, and being able to evaluate rigorously one's own creative output.

In the empirical study reported in this chapter, creativity is operationalised in terms of Torrance's definition of learner outcomes that indicate a capacity for creative thought. Torrance defines creative thinking ability in terms of fluency, flexibility, originality and elaboration (Torrance, 1974).

Fluency is defined as the capacity to provide a number of responses to a given stimulus. For example, a person who is able to provide numerous responses to the stimulus question 'How many uses can you think of for a house brick?', would be said to have high levels of ability in the fluency component of creativity.

Flexibility is defined as the number of responses to a given stimuli that are different in type. That is, if, in response to the brick question above, a person provides a large number of responses that are all concerned with using bricks for construction purposes, they would score well on fluency but not on flexibility. If on the other hand a person suggested diverse classes of uses for the brick such as construction, as a door stop, a weapon, ground up to use as paint etc, they would score well on flexibility.

Originality is defined in statistical terms as indicating that a response is original if it has a low probability of occurrence.

Elaboration is an indication of the level of additional detail a person can provide when producing a response to a stimulus question. Elaboration is taken as a measure of the completeness and clarity of a person's creative thinking.

Scores on the Torrance test of Creative Thinking Abilities are said to produce a profile of creative thinking abilities rather than a sum or average. Scores are also said to be independent. In general terms, this is so; however, a relationship does exist between scores for fluency and scores for

flexibility. Fluency is a prerequisite for flexibility in that, without a sufficiently large number of responses (fluency), there can not be a large number of responses that are different in kind (flexibility).

The creative process can therefore be described in terms of the four elements of preparation, incubation, illumination and verification. Furthermore, the development of creative thinking abilities can be assessed in terms of the four criteria of fluency, flexibility, originality and elaboration. It should be noted, however, that findings from a number of research projects question the relevance of the components of fluency and flexibility as indicators of creative thinking ability (see Mansfield & Busse, 1981, for a review).

Problem-based learning

In problem based learning (Stephien, 1993; Wallas, 1988; Ashman, 1993; Barrows, 1980) the basic learning medium is the design project . Students are presented with a design brief. The design brief identifies a problem and specifies any parameters that students may have to work within as they solve the problem. The parameters may specify quantities of materials or particular processes that may or may not be used in solving the problem.

Students engaged in problem-based learning are required to produce new and useful solutions to problems. Heuristics for achieving original solutions are presented to students together with illustrative examples. Heuristics include: fine tuning approach, the minor modification of an existing solution; major adjustment approach, that is, a major modification of an existing solution; and the joining approach, which involves bringing together two existing elements in a way not done before (Weber & Perkins, 1989; Weber, Moder, & Solie, 1990). Specific heuristics are presented as suggestions only, and students are free to use whatever strategies they prefer to generate new ideas.

Design briefs are developed in such a way that there is no one correct answer. Problem solutions are deemed to be satisfactory to the extent that they satisfy goal criteria developed from the problem statement or developed or modified during the problem-solving process (Schon, 1990). In this sense, the problems can be considered to be ill-defined (Kaufmann,

1991). The level of definition of problems presented to students in the problem-based course, examined in this study, varies over the duration of the three year course. Problems in the early stages of the course are restricted by having either materials or construction processes specified. As students progress through the course, problems became more open-ended and a wider range of materials and processes are available.

Procedural knowledge in the problem-based learning, examined in this chapter, is acquired in the following way. Students are given demonstrations of basic hand and machine tool operations, such as how to saw a piece of timber, drill a hole, etc. In the early stages of the course, demonstrations are teacher-initiated on the basis of the teacher's perception of the potential use of the skill in solving the problem. As the course progresses, demonstrations change from being teacher-initiated to student-initiated on the basis of students' identifying, through research and experimentation, the need to use a skill the students do not possess. Joining metals by electric welding or using the plasma cutter to shape sheet metal, are two example of procedures student may identify as being useful for solving a problem, but procedures that will require a demonstration and some practice.

Freehand sketching is used in three ways in the planning of solutions to problems in problem-based learning (Middleton, 1983, 1990). Sketching is used in the initial stage of problem-solving, to develop solution concepts. Sketching is then utilised in developing, articulating and fine-tuning the individual procedures required for producing the proposed solution and, lastly, sketching is used to determine the order in which the procedures are to occur in the solution sequence. The emphasis on solving three-dimensional problems in the actual workshop setting and the consequent emphasis, in that problem-solving, on sketching determined that the figural rather than the verbal forms of the Torrance Test of Creative Thinking Abilities would be utilised in the study described in this chapter.

The aims of the course were to develop problem-solving skills and acquire a wide range of practical skills using a range of construction materials and a selection of hand and power tools.

Empirical study

The study reported here involved four groups of high school students. All groups were involved in workshop-based elective subjects of three years duration. Three groups (labelled A, C and D) were exposed to teaching methods that are labelled as traditional. One group (labelled B) was involved in problem-based learning. Traditional teaching methods involved a combination of theory, demonstration and practice. That is, some content material was presented in theory lesson. Practical workshop skills were demonstrated by the teacher, and students were required to practise and demonstrate competence in performing the tasks in a manner identical to the teacher demonstration. Assessment was based on the degree of accuracy achieved by students in completing the task as specified.

The study reported here was exploratory and sought to establish the relationship between certain teaching methods and the development of creative thinking abilities.

Sample

The students were sixty-six boys and four girls. The ages of subjects ranged from fourteen to sixteen. The sample included all schools under the control of the local education authority that offered workshop classes where traditional teaching methods were employed, and all schools that offered workshop classes where problem-based learning methods were employed. Schools involved in the study were also selected on the basis of equivalence in terms of socio-economic and other factors, using data supplied by the local education authority. Teaching methods, socio-economic factors and availability determined that four schools would be used for the study. One school that employed problem-based learning and three that used traditional teaching methods were used.

Instrument

The instrument used in the study was the Torrance Test of Creative Thinking Abilities, Figural Forms A and B (Torrance, 1974). The figural

forms of the Torrance test are designed to elicit responses that can be classified using the four criteria described below. They are:

- Fluency, the number of responses within a given category of responses;
- Flexibility, the number of categories of responses;
- Originality, the number of rare or unusual responses; and
- Elaboration, the degree of additional detail applied to the response.

Validity and reliability data for the Torrance test have been established with Yamamoto (1965) obtaining reliability co-efficients within the range .6 to .85 in a three stage test-retest study. Similar results for reliability have been obtained by Goralski (1964). Torrance (1990), in a survey of studies examining the reliability of the Torrance Test, indicated that reliability measures of .9 were generally possible. A number of studies has been conducted to establish overall measures of validity for the Torrance test. Significant correlation between measures in the Torrance Test and other factors associated with creative behaviour have been established (Torrance, 1974b).

Procedure

The avoidance of actions that might create a test-like environment is an important condition for obtaining valid measures of creative thinking ability with the Torrance Test (Torrance, 1974).The tests were conducted over a six day period with the testing being carried out between eight-thirty and eleven in the morning. All tests were conducted during regular scheduled classes when students involved in the test had double periods of workshop classes. Efforts were made to ensure that students did not perceive the Torrance Test as an examination. Class teachers were instructed to simply mention that students would be trying out a new activity. Use of the word test, in relation to the Torrance test was avoided. Administration of the test was undertaken by a counsellor from the local education authority. The counsellor was familiar with the Torrance Test, but was not aware of the details of the study, or of the composition or learning experiences of student groups; thus, experimenter bias was avoided.

The main testing program was conducted after a trial test using a small sample of students from the same age group, excluding any students in the testing program. The trial was administered under conditions similar to those observed in the testing program. The trial revealed no significant problems in the administration of the test in terms of the instructions given, the physical setting for the tests, or student perceptions of, or reactions to, the test.

Analysis

The test provided raw scores for the eight components of the test, that is, scores for fluency, flexibility, originality and elaboration for each of the two forms of the test. A Kruskall-Wallis analysis of variance (Siegel, 1956) was performed for each component, between the four experimental groups. The analysis of variance was used to determine if there were any statistically significant differences between the sums of the four ranks on each component. Corrections for tied scores were made.

The Mann-Whitney U test (Siegal, 1956) was employed on those components where the Kruskall-Wallis test had indicated a significant difference between ranks. The Mann-Whitney U was employed to determine which group or groups were significantly different.

Findings

Results from the Kruskall-Wallis analysis of variance indicated no significant difference between groups in terms of fluency and flexibility, for both figural form A and B of the Torrance test. Significant differences were obtained for the measures of originality and elaboration. (See Table 5.1)

The Mann-Whitney U analysis of variance (See Table 2) indicated a significant difference between group B (the problem-based group) and groups A and C but not group D on the originality A component. On the originality B component, the score for group B is significantly different to group A but not to groups C or D. On the elaboration A component, the score for group B is significantly different to groups A and C but not to

group D. On the elaboration B component, the score for group B is significantly different to groups A, C and D.

TABLE 5.1: Kruskall Wallis Analysis of Variance of creativity across groups: All Ranks

Component	p	Component	p
Fluency A	.35	Fluency B	.9
Flexibility A	.7	Flexibility B	.7
Originality A	.02*	Originality B	.001*
Elaboration A	.02*	Elaboration B	.01*

Level of significance is .05. An asterisk (*) is used to indicate significance.

TABLE 5.2 Mann Whitney U Test of differences in creativity between group B and other groups.

Component	Groups	U	Critical Values
Originality A	B, A	37*	88
	B, C	114.5*	116
	B, D	144.5	109
Originality B	B, A	25*	88
	B, C	123	116
	B, D	130.5	109
Elaboration A	B, A	64.5*	88
	B, C	95.5*	116
	B, D	148	109
Elaboration B	B, A	36.5*	88
	B, C	54.5*	116
	B, C	70*	109

Level of significance is .05. An asterisk (*) is used to indicate significance.

TABLE 5.3: Summary of Mann Whitney U Test results from table 5.2 (Significant differences between Group B and other groups)

Component	A	C	D
Originality A	✓	✓	-
Originality B	✓	-	-
Elaboration A	✓	✓	-
Elaboration B	✓	✓	✓

Levels of significance in 0.5. A tick (✓) is used to indicate significance.

Discussion of Results

The analysis of results provides indications that students engaged in problem based learning display higher levels of creative thinking ability than students engaged in traditional workshop learning activities, in terms of originality and elaboration.

The analysis also revealed a number of apparent anomalies. Figural forms A and B should provide similar results; however, group C was not significantly different to B on the originality component of form B, but was on form A. In addition, group B was significantly different to group D on form B but not on form A. A more significant finding was that group B was only significantly different to group D on the elaboration component of form B. Thus for three of the four measures of creative thinking abilities (originality and elaboration forms A and B) the problem based learning group (B) displayed no significant difference to one of the traditional learning groups (D).

In an attempt to discover the reason for the anomalies in the results a number of steps was taken. The testing schedule was examined to determine if any events had occurred that may account for the results. In addition a number of staff from school D was interviewed. Information was elicited concerning:

- the elective subjects students in group D studied on other elective lines;
- the level of stability in group D, that is, the number of students who had joined or left the group since its formation; and
- the possibility of any problem-solving courses in the school.

A positive response was obtained for question three, in that, problem-solving appeared to be of greater importance as a teaching strategy in Science, in that school, than was previously believed to be the case.

As to the reason why no significant difference was obtained among groups on the measures of fluency and flexibility, the following suggestion is offered. The problem-solving process used by group B (problem-based learning group) does not demand a high degree of fluency from students in the responses they provide to presented problems. Emphasis is placed on the novelty and usefulness of responses to problems, rather than on the generation of many responses.

The lack of any significant difference between the problem based group (B) and the traditional groups (A, C & D) in terms of flexibility, can be explained in terms of the relation between fluency and flexibility. A high score for flexibility indicates that, of the responses provided, there was a significant number of different categories of responses. Therefore, as group B did not achieve a significant score on the fluency component, they could not achieve a significant score on the flexibility component.

Fluency and flexibility have been regarded as indicators of divergent thinking ability and have been regarded as important elements of creative thinking (Guildford, 19[illegible]). Test items designed to elicit divergent thinking responses have been built into a number of tests of creative thinking ability, including the one used in this study. However, more recent studies have suggested that divergent thinking is not a good indicator of creative thinking. A longitudinal study by Getzels and Csikszentmihalyi, (1976) found no evidence of a link between divergent thinking and creative thinking. Getzels and Csikszentmihalyi (1976) found that problem-finding was a more reliable indicator of creative performance. That is, people who are not content to accept the first representation of a problem and persist in searching for new ways to represent problems, are more creative. In an extensive review of studies of divergent thinking in scientific thought,

Mansfield and Busse (1981) concluded that there was no evidence linking divergent thinking ability to creative performance. The results of this study are therefore consistent with findings suggesting creative thinking ability is not related to performance on a divergent thinking task.

Disregarding the results for fluency and flexibility, then, the results indicate that originality (striving for new ways to represent problems) and elaboration (the level to which the representations can be articulated), as indicators of creative performance, were enhanced by problem-based learning. The conclusion is thus drawn that there was a relation in these classes between problem-based learning in workshop classes and these two indicators of creative thinking abilities.

Conclusions

This chapter began with the reflection (from chapter 1) that the nature of work has changed substantially over the last decade (Laur-Ernst, 1992). To respond successfully to the changed nature of work, individuals need to be able to handle complex indeterminate situations where no rules apply, and need to use imagination, improvisation and creativity in solving problems.

The argument is also put that technical expertise includes the ability to do more than perform routine technical tasks. Expertise requires (among other abilities) the ability to generate skilled performance as technical tasks become complex and as situations and processes change. Technical expertise also involves the ability to innovate.

Creative thinking has been examined in terms of available research and a number of conclusions drawn. Creativity is defined as a universal attribute (Hayes, 1989) that can be developed through appropriate learning experiences. It is argued that learning experiences, where the learner is engaged in formulating new and original responses to complex problems, will develop creative thinking ability. In a limited experimental study, it has been shown that problem-based learning in workshops can increase such indicators of creativity as originality and elaboration. However, current approaches to vocational learning appear to concentrate on teacher-centred activities, based on the presentation of information, demonstration of skills and teacher monitoring (see chapter 6). Little emphasis appears to

be placed on the acquisition of creative thinking skills. The emphasis in competency-based training (CBT) on performance assessment, based on well-described tasks, may be antipathetic to the kinds of learning tasks students will need to engage in to develop creative thinking skills. Meeting the needs of a workplace characterised by change and uncertainty, while meeting the requirements of CBT assessment will provide a challenge for vocational education.

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6 Development of student expertise in TAFE colleges

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Abstract *This chapter examines the cognitive structures needed for expertise and their development in TAFE colleges. It is based on a model of teaching and learning which links the characteristics of learning settings, teacher and student activities, learning environment (classroom and press) and cognitive structures.*

It is argued that vocational students need to develop structured deep conceptual understanding in their technical fields, skills for expert action on routine tasks and the ability to use higher order thinking to address problematic and non-routine tasks and situations. That is, an exclusive focus on the development of specific skills is inadequate in vocational education because it develops expertise only on routine and predictable tasks. Similarly, an exclusive focus on information about skills without the development of deep conceptualisation in that technical area is inadequate because workers are unable to perceive problematic tasks at multiple levels of abstraction, link the features of problems to a particular level and apply procedures linked to that level. While there is little evidence of higher order thinking by learners in the settings examined, even an exclusive focus on higher order thinking would be inadequate without a rich linked propositional base on which it could operate.

What is required is the design of learning experiences where all of these structures are valued and their simultaneous development encouraged.

The results of a study of teaching and learning in several TAFE colleges across several trade and technical areas is reported. From video-recordings of teacher and student actions, it is concluded that the primary initiator of learning activities in TAFE colleges is the teacher, the primary source of information is the teacher and the primary focus is on the provision of information. It was found that practical and theory classes were different from each other in terms of teacher and student activities and the learning environment that was created. Practical classes were superior in terms of their emphasis on higher order thinking.

The implications of these results are examined and suggestions made about how to improve teaching and learning in vocational education settings such as TAFE. It is concluded that, in these TAFE settings at least, there is not adequate emphasis on the simultaneous development of the full range of structures needed for expertise in both routine and non-routine situations. Challenges for the Competency-Based Training teacher are also raised.

Introduction

It is argued in Chapter 1 that *technical expertise* can be thought of as the ability not only to perform routine technical skills, but also to:

- generate skilled performance as technical tasks become complex and as situations and processes change,
- reason and solve technical problems,
- be strategic,
- innovate and
- adapt.

That is, it is defined to included not only *near transfer*, but also *far transfer* — near transfer for tasks similar to those on which the learner has some experience and far transfer for tasks which are unfamiliar and for which similarities to previous tasks are not apparent (Mayer, 1974; Royer, 1979). A variety of categories of cognitive structures (representations of knowledge in memory) is involved in these actions. The structures include: propositional or declarative knowledge (conceptual understanding — principles, facts, theories, propositions, information); specific procedures (knowledge for securing a specific known goal); and higher procedures (knowing how to solve problems presented by unfamiliar situations) (Anderson, 1982; Evans, 1991b; Ryle, 1949; Scandura, 1981; Stevenson, 1986a, 1991).

It is argued in this chapter that expertise is the ability to coordinate conceptual knowledge, specific procedures and higher order procedures to meet the challenges of new and unfamiliar situations. This coordination requires deep and structured understanding and the association of specific procedures with conceptual knowledge at various levels of abstraction. It also requires higher order procedures for interpreting new situations, determining a problem-solving strategy, monitoring progress in achieving

task goals and evaluating both the outcomes of cognition and the processes used to achieve them. In this chapter, an overall model of the teaching/learning process in vocational education is developed from a cognitive stand-point and the results of a research study of TAFE classes is presented.

A cognitive model of teaching and learning

It is learners' interpretation of learning tasks and their subsequent task engagement which determine what and how much they learn (Posner, 1982). According to Posner, learners shape their tasks on the basis of both their own cognitive structures and the external resources available to them. Thus, it is not just the task that a teacher sets that determines the learning that takes place — it is the learners' construction of that task.

We cannot assume that teaching and learning involve a factory-like process where teacher-supplied resources automatically leads to pre-specified behaviours. Changes in behaviour are the result of changes in underlying cognitive structures — new specific procedures, new conceptual understanding and new higher order procedures (See Chapter 1). In addition, it is underlying structures themselves that shape the kind of learning that takes place through interpretation of tasks and engagement in them. Take for example learning to use a lathe. The ability to understand the learning task depends on existing knowledge of the nature and functions of lathes, their controls and how they work. The ability to engage in the learning task depends on existing machining skills or existing sub-skills, and on how the learning task is interpreted. Different learners will see the learning task differently, depending on their existing conceptions of lathes, the place of lathes in their conceptions of workshop equipment generally and their different levels of skill in machining. The ability to engage in the learning task also depends on differences in abilities to confront new situations and new problems. Further, what the apprentice turner takes away from the learning task will be changes in these same kinds of cognitive structures: new understanding, new skills, new ways of going about solving problems, and it is these structures that lead to changed behaviour. Moreover, for each learner, the changes will be different

depending on their individual mental constructions of lathes and working on lathes.

This view of learning places learner cognitive activity at the centre of the teaching learning process. For one to learn, one needs to be able to access the learning task through being able to interpret it and engage in it. One needs to be able to relate the nature of the learning task to existing conceptual knowledge for it to be meaningful, and one needs to be able to see the relationship between the task and one's existing abilities (procedural knowledge) in order to begin to work on the task. In addition, each learner's learning task will be idiosyncratic to that learner — so, too, will the learning outcome.

However, it is not only the learners themselves that influence the learning that takes place. The learning setting itself has an influence on the tasks in which learners will actually engage (Barker, 1978; Kounin & Sherman, 1979; Moos 1979; Murray, 1938; Pace & Stern, 1958). According to Moos (1974), the dimensions of a setting can be considered in terms of relationship (extent to which people are involved in the environment, support and help each other, and are spontaneous, free and openly expressive), personal growth or goal orientation (extent to which people are involved in personal development and self enhancement) and system maintenance and change (extent to which the environment is orderly, clear in expectations, maintains control, and is responsive to change). A person makes a cognitive appraisal of the setting and this leads to activation or arousal (Moos, 1979). This cognitive appraisal would involve coordination of propositional and procedural knowledge as discussed in Chapters 1 and 8. The kinds of procedural knowledge which settings activate in students can be categorised in terms of their generality in meeting goals within the setting — first order if specific procedures for routine action are activated; second order if general problem-solving procedures are activated.

As teachers structure learning environments and the tasks on which learners can work, they clearly have an influence on these dimensions. The environment itself influences learner activity, and so do learners' individual characteristics. Thus, it is posited that the relationships as depicted in Figure 1 exist in teaching and learning.

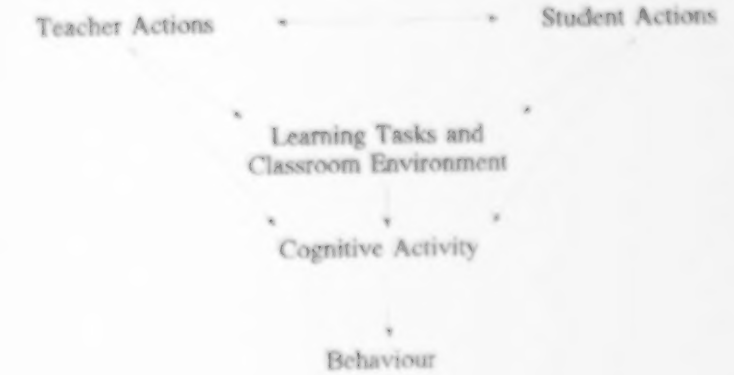

FIGURE 6.1 A cognitive model of teaching and learning relationships

Desirable characteristics of teaching and learning in TAFE colleges

Thus, vocational students need to develop structured deep conceptual understanding in their technical fields, skills for expert action on routine tasks and the ability to use higher order thinking to address problematic and non-routine tasks and situations. That is, an exclusive focus on the development of specific skills is inadequate in vocational education because it develops expertise only on routine and predictable tasks. Similarly, an exclusive focus on information about skills without the development of deep conceptualisation in that technical area is inadequate because workers are unable to perceive problematic tasks at multiple levels of abstraction, link the features of problems to a particular level and apply procedures linked to that level. Even an exclusive focus on higher order thinking would be inadequate without a rich linked propositional base on which it could operate. What is required is learning experiences where all of these structures are valued and their simultaneous development encouraged.

The model of teaching and learning, described above, has been examined in two studies of classes in TAFE colleges, over a two year period. The studies are both exploratory and descriptive. They seek to delineate the nature of teaching and learning activities, the cognitive structures developed in these classes and the relationships between the two sets of variables. Classes were chosen in a variety of trade areas, across a number of colleges, involving both theory and practice, with apprenticeship and other students and new and experienced teachers. Lessons were video-taped, students and teachers were interviewed and a number of instruments was administered.

The studies were undertaken prior to the progressive implementation of Competency-Based Training (CBT) in Australia, and seek to provide a basis against which the tenets of CBT can be appraised. Elsewhere we have argued that practices associated with CBT can lead to the dis-aggregation of knowledge, can over-emphasise the observable and the predictable and can leave neglected the development of higher order and general cognitive provisions needed to adapt to change and solve problems in the work place (Stevenson & McKavanagh, 1992).

Amongst other objectives, the studies describe the current relative emphases on the development of different categories of cognitive structures. Each of the two studies is detailed below.

Based on the concepts discussed above, our expectations of teaching and learning in TAFE colleges, if expertise is the goal, are as follows. We would expect to find learners engaged in problematic tasks, working out ways in which to proceed, evaluating different strategies and monitoring their own performance in terms of their own conceptual understanding. We would expect to find them working on a wide variety of complex problems that lend themselves to a deepening of conceptual understanding through reflection on the differences among the problems. We would also expect to find learners gaining the capacity to view new problems at different levels of abstraction and executing appropriate problem-solving actions at the relevant level. We would expect that teachers would be acting as facilitators, assisting and discussing strategies with learners as they confronted problematic situations. We would expect to find the teachers extracting from practical tasks the salient principles that differentiated that task from other similar tasks and tasks at different levels of generality.

Empirical studies

Selected classes

Characteristics of the classes examined in Study 1 and Study 2 are given in Table 1. Overall forty-nine theory, practical and integrated lessons across five trade areas and five TAFE Colleges in Queensland were included in the sample. Trade courses which were regarded as unique to TAFE were chosen — Motor Mechanics, Electronic Process Control, Fitting and Machining, Butchery, and Carpentry and Joinery. To ensure that the sample included representative TAFE learning settings, fourteen teachers with a range of experiences were selected to participate in the studies. New teachers were defined as those still in training or within two years of having completed their initial Diploma or Degree programme. Two to four lessons from a syllabus unit for each teacher were included. Prevocational, apprenticeship and post-apprenticeship students were sampled. Teachers and all but three of the 188 students were male. The average student age was 20.0 years.

Measurement

Instruments were selected to measure teacher and student actions, classroom environment and cognitive structures (See Figure 1) and are summarised in Table 2 for each study. In Study 1, instruments were used which permitted at least two measures of each variable. Based on these findings, in study 2, a new questionnaire was developed (Knowledge and Learning Questionnaire (KALQ)). Details of data collection and instruments follow.

TABLE 6.1: TAFE classes in the sample

TAFE College	Trade Area	Teacher Experience	Class Mode	Lessons Study 1	Lessons Study 2
A	1	Beginning	Theory	2*	
			Practical	1*	
		Experienced	Theory	3*	
	2	Beginning	Theory	1	
			Practical	2	
		Experienced	Theory	1*	
			Practical	2*	
B	1	Beginning	Theory	2*	
			Practical	1*	
		Experienced	Theory	3	
			Practical	3	
	2	Experienced	Integrated	6	
C	3	Beginning	Theory	2	
		Experienced	Theory	3	
D	4	Beginning	Theory		3
			Practical		2
		Experienced	Theory		2*
			Practical		2*
E	5	Beginning	Theory		2*
			Practical		2*
		Experienced	Theory		2*
			Practical		2*
Totals				32	17

* Lessons with pre-vocational students (N=16).

* Lessons with post-apprenticeship students (N=8). Other lessons were with apprentices.

Technical problems with equipment prevented use of video recordings with five lessons in Study 1.

TABLE 6.2: Instruments

Classroom variable	Instrument	Study 1	Study 2
Teacher and student actions	Coding videotapes	✓	
	Teacher interviews	✓	
	Student interviews	✓	
	Knowledge & learning questionnaire (KALQ)		✓
Cognitive structures	Coding videotapes	✓	
	Knowledge & learning questionnaire (KALQ)		✓

Video-recording and video-coding schedule

In video-recording lessons, the camera operator focused on the teacher and on student interactions with the teacher to capture those activities with direct teacher involvement in line with Brophy and Good (1986) and Flanders (1965). These interactions and the corresponding group size, teaching aids and inferred knowledge structures were coded as *foreground* events — defined as teaching or learning in which the teacher was engaged. For example, the teacher may have been explaining a theoretical concept to the entire class. However, sometimes, when the teacher actions involved only part of the class, other actions occurred with the other students. These latter actions were defined as *background*, but are not reported in this chapter. For example, the teacher may have been monitoring the work of a single student completing an exercise (foreground) while the remainder of the class was working individually on the same or different exercises (background).

The foreground activities in each class were coded from a schedule (Table 3). A code was assigned to the principal foreground (and background where present) actions every minute. The action which occupied the greatest time interval during the minute was the one used to determine the appropriate code. Initial pilot instruments for coding activities and inferred cognitive structures were based on timing the length of classroom events and assigning a code and time to each event. However, considerable inference was involved in determining whether events were discrete or parts of larger events. It was therefore decided to code events over fixed

time intervals. Following trialing of time interval lengths ranging from 30 seconds to 3 minutes, one minute intervals were found to reflect the range of discrete instructional events and the range of cognitive structures being developed in actual classes. If no teaching or learning relevant to the lesson was apparent in both foreground and background, then that minute was deleted from the analysis. Situations like this occurred, for example, when there was a short break or when the teacher was discussing travel arrangements for a forthcoming field trip or waiting for teaching aids to arrive.

The analysis of variables from video-recordings (apart from analysis of proportions of total time in each category) refers only to the foreground action. There is a limitation of this approach — since students completing questionnaires may have been reflecting not only on the foreground action in the lesson, but also any background action, comparisons among video-coded data and data from questionnaires must be treated with caution. However, student perceptions provided in interviews accorded well with foreground data from video-recordings.

Initial sub-codes for inferred cognitive activities were based on categories suggested by the literature (Anderson, 1982; Evans, 1991a, 1991b; Ryle, 1949; Stevenson, 1986a, 1986b, 1991) (See Chapter 1), but as trialing proceeded, these categories were modified to capture more of the observable teacher and student behaviour and inferred categories of cognitive activity. The final codes were: use of knowledge that; use of knowledge 'about how'; use of specific procedures; use of higher order procedures; and monitoring. Knowledge 'about how' was introduced because teachers and students were often engaged in interactions which involved explanations about how a procedure should be undertaken without either teacher or student actually preforming the procedure. This category is similar to that of 'potentially knowing how' of Taylor (1991) and Taylor and Evans (1985). The category, monitoring, was introduced to capture the action where the teacher moved around, checking on student procedures, and correcting techniques and approaches; and where students used teacher evaluative comments to modify their knowledge and strategies.

TABLE 6.3: Categories and coding schedule for teacher and student actions and cognitive structures

1. TEACHING / LEARNING TECHNIQUE

N Pause or no instruction for 40 or more seconds. (No further coding.)
P Presenting verbally or presenting by demonstrating. Student of teacher providing information or demonstrating procedures.
E Eliciting a verbal response or eliciting an action from others.

2. INITIATION

I Interaction with students initiated by teacher.
S Student(s) initiate interaction with the teacher or other students.
R Student action initiated by a resource, such as written instructions on the board, in a manual or on an exercise sheet. This code occurs only in the background.

3. GROUP SIZE

W The whole class (i.e. everybody).
F Teacher and more than one student, but fewer than the whole class). (i.e. a few students).
O Student working on their own (in the background) or alone with the teacher (in the foreground).

4-6. RESOURCE (Teaching aids as a source for learning)

W Written verbal materials in use (e.g. words on an overhead transparencies, board, in a text or manual, or in class notes, tables of words and numbers, alphanumeric codes).
I Image in use (e.g. diagrams, formulae, equations, pictures, cartoons).
C Realia or concrete objects in use (e.g. materials or equipment or other objects).
X Teaching aid not in use.

7. COGNITIVE ACTIVITY

T Using propositional knowledge or knowledge that (e.g. information, knowledge about things, facts or concepts).
A Using knowledge about how to perform a skill, without actually doing it (i.e. not being shown how, but being told how).
Y Watching demonstrations of or performing a specific skill (first order procedure), receiving techniques from others, rather than deducing it for oneself, performing a known action (e.g. copying), performing a specific technique, method or algorithm).
G Using a higher order procedure (e.g. students working out a strategy or procedure for themselves).
M Teacher monitoring, checking and correcting results, techniques and approaches of students. (Used only in the foreground).

Notes: (1) A code letter from each category is selected each minute to make a seven-part whole code, e.g. PLWACT (Teacher presents knowledge 'that' to the whole class using written materials, images and concrete objects).

(2) A main code is a four-part code, with a letter from each of the categories 1,2,3, & 7 e.g. ESFA (A few students elicit knowledge 'about how' to do something).

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The final schedule incorporated seven categories of coding for teacher and student actions, classroom resources and inferred cognitive structures. This seven-part code is referred to as the whole code. Each whole code can be read as a sentence which describes aspects of the classroom action. Each part of the code corresponds to the subject, verb, direct or indirect object or qualifier of the sentence represented (Table 4). For example, PLVWICT can be read as: The teacher (L) presents (P) information (T) to the entire class (V), using written material (W), images (I) and concrete objects (C) as aids. Various parts of the code (sub-codes) also have meaning in terms of actions and sentences and are treated separately in some analyses. A four-part code, referred to as a main code (or main sub-code or main actions), is used in several analyses. For example, ESFA can be read as student(s) (S) elicit (E) knowledge about how to perform a skill (A) in a small group (F).

TABLE 6.4: Reading Video Codes as Sentences

Category (See table 6.3)	Function in sentence	Example
2	Subject	L teacher
1	Verb	P presents
7	Direct object	T propositional knowledge
3	Indirect object	V to the whole class
4-6	Qualifiers	W using written material

A sub-code of X was used to denote absence of any of the categories of learning aids and a sub-code of N was used to denote an absence of instruction, in which case all other categories were also coded X. To increase reliability, each lesson was coded, independently, by two or three coders, and all differences reconciled jointly by the researchers.

Each class was also coded for diversity which was defined as the total number of different kinds of seven-part codes for that class.

Interviews

Parallel schedules were used to interview the teacher and two students after each lesson. Two questions were asked — one relating to what was taught and one to how it was taught. The responses were classified in terms of use of cognitive structures (Table 5) and analysed in terms of agreement and disagreement between students and teacher. Agreements were compared with data from video-coding.

TABLE 6.5: Teacher and Student Interview Questions and Coding Categories

Coding Categories	Question 1 What were you teaching? (What did you learn?)	Question 2 What techniques were you using? (How did you learn this?)
Information, Facts, Theories, Principles		
Information about Skills (Goals, Steps, Restrictions...)		
Specific Abilities (Methods, Techniques, Procedures, Skills)		
Higher Order Skills (Problem-solving, Planning, Analysing, Evaluating, Monitoring, etc)		

Procedures and analyses

For Study 1, lessons were video-recorded as they were conducted and the teacher and two students, selected by the teacher, were interviewed, separately, at the conclusion of each lesson. The Knowledge and Learning Questionnaire was administered to the whole class at the end of each lesson, as shown in Table 2. Measures of all variables in this study can be expressed in terms of individual classroom lessons, and this is the primary unit of analysis. The minute is the unit of analysis among video-coded variables. Interview data was processed by content analysis and all statistical analyses were undertaken using SAS (SAS Institute, 1985).

Findings

Findings for each study are given below, in turn.

Study 1

Of the 2,309 coded minutes, 48% involved only foreground action; 9% only background and 42%, both foreground and background. The total percentage of minutes in which foreground action was present (i.e. teacher engaged in the interaction) was 90%.

Validity of coding schedule

To validate the approach taken in video-recording and coding, and to address the problem of video-recording only foreground actions, interview data was compared with coded data from recordings. Table 6 gives the most frequent (modal responses) to the two interview questions and the top ranking one-part video codes and the top ranking seven-part codes. Clearly, at this high level of analysis, there is a close correspondence between interview data and video-coding.

TABLE 6.6: Comparison of modal interview responses and top ranking foreground video codes

Modal Response to Interview Questions		Rank Order of Video Codes			
What was taught/learned?	How was it taught/learned?	One part code Code and meaning	%	Seven part code Code	%
Knowledge that, including: · new or additional info · conceptual understanding · principles · calculations · theory	Teacher centred, including: · saying · explaining · demonstrating · revising · recapping	L Teacher	77	NXXXXXX	9
		P Presentation	59	PLVWXXT	7
		W Written material	51	PLVWIXT	6
		V Everyone	48	ELVWXXT	4
		C Concrete material	44	PLVXXXT	3
		T Information	40	PLOXXCY	3
		I Image or picture	38	PLOXXCA	3
		E Elicitation	32	ESOXXCA	3
		O One student	26	PLVXXCT	3
		A About how	21	PLOXXCM	2
		F Few	16	PLOWIXM	2
		M Monitoring	16	PLVXXCA	2
		S Student	15	PLFWICM	2
		Y Specific procedure	13	ELVWIXT	2
		N No action	9	PLFXXCA	2
		G Problem solving	2	PLVWIXA	1

Overall emphases in teaching and learning

The main foreground coding permitted sixty unique four-part main sub-codes. Forty-seven of these were actually used for the 2,309 minutes of action across 15 theory and 12 practical classes of 10 teachers, as a whole. However, 20 codes occurred at frequencies of less than 15 in 2,309. The remaining top ranking sub-codes (27 in all) account for 96 percent of all foreground action and knowledge categories (Table 7). The mode, 'Teacher presents information to the whole class' (PLVT) accounts for 23 percent, and the top six sub-codes account for 59 percent of all actions. This broad view of the teaching and learning action in TAFE classes seems to imply a high level of uniformity amongst teachers, but a finer analysis reveals some diversity and differences between settings, as discussed below.

TABLE 6.7: Percent Time Most Frequent Main Foreground Actions, Overall and by Teacher (Modes highlighted; 27 lessons, 2,309 minutes) (Study 1)

Top Ranked Twenty-seven Main Actions Overall				Top Ranked Six Main Actions for Each Teacher									
				Experienced Teachers (N=6)						New Teachers (N=4)			
Rank	Sentence to Represent Main Action Code	Code	%										
1	Teacher presents information to the whole class	PLVT	**23**	10	**18**	**61**	**34**		**27**	14	14	**46**	**15**
2	Teacher elicits information from the whole class	ELVT	10		**18**	5	21			**18**		27	9
3	Teacher not active, but students working in the background	NXXX	9	9	9	2	13	20	9		9		
4	Teacher presents knowledge 'about how' to the whole class	PLOA	7			11	10	6	13		10	4	
5	Teacher initiates monitoring of one student	PLOM	5	11				5		17	15		
6	Single student initiates knowledge 'about how' from the teacher	ESOA	5	7			5	10	9	12			
7	Teacher shows a specific skill to one student	PLOY	4					**24**					
8	Single student initiates monitoring by the teacher	ESOM	4	**24**									
9	Teacher presents knowledge 'about how' to one student	PLOA	4	6				15		9			
10	Teacher initiates monitoring of a small group	PLFM	3		7						**18**		
11	Teacher presents specific skill to the whole class	PLVY	3			8			11				
12	Teacher presents knowledge 'about how' to a small group	PLFA	3		14								
13	Teacher presents a specific skill to a small group	PLFY	2										7
14	Teacher presents information to a small group	PLFT	2										11
15	Single student elicits information from the teacher	ESOT	2									9	
16	Teacher initiates monitoring of the whole class	PLVM	2						9		8		
17	Teacher elicits knowledge 'about how' from the whole class	ELVA	2				5			8		2	
18	Teacher elicits problem solving from a few students	ELFG	1										6
19	Teacher elicits a specific skill from the whole class	ELVY	1			4							
20	Teacher elicits a specific skill from a small group	ELFY	1		6								
21	Teacher elicits information from a small group	ELFT	1										7
22	Teacher elicits monitoring of a small group	ELFM	1										
23	Teacher elicits problem solving from the whole class	ELVG	1										
24	Student elicits knowledge 'about how' from a small group	ESFA	1										
25	Single student elicits a specific skill from the teacher	ESOY	1										
26	Student elicits information from a small group	ESFT	1										
27	Student presents information to the whole class	PSVT	1									7	
	Percent of Total Action from Top Activities		96	66	71	92	87	80	77	78	74	95	54
	Total Number of Different Types of Activity (Codes)		47	20	26	18	17	20	21	11	27	11	34

Table 7 also gives the six most frequent four-part sub-codes and percentages (with modes highlighted) for each of the six experienced and four new teachers. The pattern indicates some diversity of teaching styles but with no overall pattern of differences between experienced and new teachers. With the exception of one teacher, more than 65 percent of teaching time can be described by a different set of six modal main sub-codes for each teacher. The exceptional case, a new teacher, used 34 of the 47 sub-codes observed in the entire study, so that the top six sub-codes capture only 54 percent of the total lesson time for this teacher. Four of the 47 sub-codes were also unique to this teacher, but each occurred only once in 2,309 minutes. This teacher demonstrated a more varied teaching style than any other in the study. The mode for this teacher is also the mode for five other teachers and for the sample as a whole, so that this teacher, while exceptional, is not so distinct as to need exclusion from further analysis. One other teacher has an unusual profile in that the set of top six sub-codes for that teacher does not contain the sample mode of PLVT. This is explained by the fact that this teacher taught only practical classes and those classes have distinct characteristics as discussed below.

Differences among types of classes

Classroom actions were compared across the different lesson classifications in the study — teacher experience, type of student (apprenticeship or prevocational), type of lesson (theory or practical), trade area and college. The fourteen most frequent foreground main actions (accounting for 81 percent of total lesson time) were tabulated against the top five main actions for each classification variable (Table 8). Percentage of time for each action is shown, with modes highlighted, and the diversity of actions indicated by the total number of distinct codes.

TABLE 6.8: Percent Time Engaged in Most Frequent Main Foreground Actions, by Experience of Teacher, Student Type, Lesson Type, Trade Area and College (Modes are highlighted; N = 2,309 minutes) (Study 1)

Top Fourteen Actions		Top Five Actions												
Sentence to Represent Code	Code	All	Teacher Experience		Apprentice/ Prevocational		Theory/ Practice		Trade Area			College		
			Exp	New	App	Prevoc	Th	Pr	1	2	3	A	B	C
Teacher presents information to the whole class	PLVT	**23**	**25**	**20**	**19**	**29**	**40**		**14**	**25**	**39**	**12**	**28**	**39**
Teacher elicits information from the whole class	ELVT	10	8	13	8	11	16		11		23		9	23
Teacher not active, but students working in the background	NXXX	9	10	6	10	7	6	12	7	10	8	12	6	8
Teacher presents knowledge 'about how' to the whole class	PLVA	7	7		6	8	9			9	7		6	7
Teacher initiates monitoring of one student	PLOM	5		8		7				7				
Single student initiates knowledge 'about how' from the teacher	ESOA	5						7				9		
Teacher shows a specific skill to one student	PLOY	4	7		7			8		7		10		
Single student initiates monitoring by the teacher	ESOM	4						8	8			9		
Teacher presents knowledge 'about how' to one student	PLOA	4						7						
Teacher initiates monitoring of a small group	PLFM	3		6									7	
Teacher presents specific skill to the whole class	PLVY	3					5							
Teacher presents knowledge 'about how' to a small group	PLFA	3							6					
Teacher presents information to a small group	PLFY	2												
Single student elicits information from the teacher	PLFT	2									4			4
Percent of Total from Top Actions		81	57	53	50	61	76	42	46	59	82	52	56	82
Total Number of Different Types of Action (Diversity)		47	42	40	43	38	36	38	42	38	20	30	43	20

The dominance of teacher presentation to the whole class (PLVT) is again obvious, this being the mode for all categories except practical classes. While there are some differences between classes of new and experienced teachers, between classes with apprentices and prevocational students, and among trade area and college, the main apparent difference is between theory and practical classes. Not only is the mode different for theory and practical classes, but only one of the top five actions (teacher not active, but students working in the background) is common to both. The difference between percent of total action accounted for by the top fourteen actions (76 for theory; 42 for practical) also indicates that, for theory classes, a few actions are used frequently, in contrast to practical classes where actions are more varied.

There are less striking differences among trade areas, where actions in Trade 3 are more uniform than in other trades (20 compared to 42 and 38 different actions) and where there is more presenting and less eliciting for Trade 2 than for Trades 1 and 3.

Thus, there is a degree of diversity of teaching and learning activities across teachers and, in some cases, within the classes of a single teacher. Nevertheless, the most common teaching actions for individual teachers is the presentation of information to the whole class. Actions emphasised in theory classes appear to be qualitatively different from those in practical classes and Trade Area 1 has less emphasis on the elicitation of information from the whole class by the teacher. The next section explores further the patterns in TAFE classrooms by comparing theory and practice classes.
Differences between theory and practice

To achieve more detailed comparisons between theory and practice, results for each of the 15 one-part foreground codes for each lesson were summarised as the percentage of total time (See Table 9). An additional variable of diversity of actions was calculated as the total number of distinct actions for each lesson. To establish differences between theory and practical classes, the data for the 27 classes on the 16 variables were analysed using a multi-variate analysis of variance for overall effects and using a t-test for each of the variables separately. There are differences ($p<0.001$) between the theory and practical classes on the foreground variables as determined by a multi-variate analysis of variance ($F = 22.96$; df

= 15,11). Twelve of these variables show significant differences between theory and practical classes using a t-test (Table 9).

TABLE 6.9: Differences between Theory and Practical Classes on Sixteen Foreground Variables, as Percent of Lesson Time (Study 1)

	Theory (N=15)		Practical (N=12)		t-Test
Variable (One part code)	Mean	SD	Mean	SD	Direction[1]
Diversity (-)[2]	9.7	4.4	14.3	4.1	P>T***
Presenting (P)	62.4	19.5	53.8	13.4	
Eliciting (E)	30.3	16.7	34.9	17.2	
Teacher Initiation (L)	85.1	10.9	66.8	12.1	P<T***
Student Initiation (S)	8.3	7.5	21.9	13.3	P>T**
Whole Group (V)	80.2	18.3	13.6	14.4	P<T***
Small Groups (F)	2.4	3.1	33.3	35.8	P>T*
One Student (O)	10.7	12.0	41.8	31.7	P>T**
Written Materials (W)	65.0	22.6	37.3	34.4	P<T*
Visual Images (I)	39.7	28.7	33.3	28.7	
Concrete materials (C)	12.3	15.4	78.2	14.0	P>T***
Propositional (T)	60.6	25.9	16.7	13.2	P<T***
About Procedures (A)	15.6	10.5	26.8	13.1	P>T*
Specific Procedures (Y)	7.7	9.7	17.5	10.8	P>T*
Higher Procedures (G)	1.1	2.2	3.4	5.1	
Monitoring (M)	8.4	14.4	24.2	19.2	P>T*

[1] P=Practical; T=Theory; P>T means the variable is larger for P than T, significant at the .05 (*), .01 (**) or .001 (***) level

[2] Measured as number of different seven-part codes

The types of cognitive activity in practical and theory classes were also significantly different. In practical classes there were more demonstrations and more practising of specific skills (first order procedural knowledge) and more attention to knowledge about skills such as these. There was also more monitoring by the teacher. By contrast, in theory classes, non-skill propositional knowledge (information) predominated.

Actions in practical classes were more varied than those in theory classes. During practical sessions, students initiated more actions; engaged in more one-to-one and small group interactions; and used more concrete learning materials. On the other hand during theory classes, teachers initiated more actions; interacted with the whole class more often; and used more verbal information.

These data indicate that distinctive features of theory classes compared with practical classes are the teacher-centred, whole class action focused on information from spoken words and text, with less emphasis on procedural and intellectual skills. The distinguishing features of practical classes were the greater diversity of activities, more centred on an individual or small groups of students interacting with the teacher. Equipment and other concrete materials were used to demonstrate or practise skills, or to furnish a backdrop for information about how to perform specific skills. There was also greater monitoring by the teacher in practical classes. These data suggest that background action needs further analysis in practical lessons, but this analysis is not reported in this Chapter.

Study 2

Sources and processes of teaching and learning activities

From the Knowledge and Learning Questionnaire (KALQ) the relative ranks of different possible sources of learning content (Table 10) and the relative emphases on different types of cognitive activity (Table 11) were calculated. This analysis confirmed the teacher as the main source of learning content for both courses, in both theory and practical classes. For practical classes, irrespective of course, the next ranked source was working it out for oneself, followed by other students, and, finally using textbooks or manuals.

The patterns for theory classes is mixed; but working it out for oneself is consistently ranked more highly than other students as a source, as in practical classes.

TABLE 6.10: Relative Sources of Learning Content

Source of Learning Content	Overall (n=210)	Theory		Practical	
		Course A (n=48)	Course B (n=65)	Course A (n=43)	Course B (n=54)
Teacher	1	1	1	1	1
Working it out for oneself	2	2	3	2	2
Textbook or manuals	3	4	2	4	4
Other students	4	3	4	3	3

TABLE 6.11: Relative Emphasis on Types of Cognitive Activity (Rank order, 1 is highest)

Cognitive Activity — Learning:	Overall (n=210)	Theory		Practical	
		Course A (n=48)	Course B (n=65)	Course A (n=43)	Course B (n=54)
new information	1	1	1	1	3
about how to do new things	2	2	4	3	1
to relate new information to things you already knew	3	3	2	6	6
to apply skills and information to new problems	4	4	3	5	4
to apply information in new situations	5	5	6	2	7
new skills	6	6	5	4	1
to relate new skills to things you could do already	7	7	7	7	4
to organise information better	8	8	8	8	8

The study indicated a higher relative emphasis on acquiring new information and information about how to undertake procedures, over the organising of this information and the relating of these procedures to existing procedures. The pattern in theory classes for other ranks was more consistent than for practical classes. To investigate further the relationships among sources of learning content and cognitive activities, multiple regressions of learning sources were performed on each cognitive activity (Table 12). This table confirms the teacher-centredness of learning experiences involving new information, new skills, information about new skills, and new problems. Relying on one's own resources rivalled the teacher as a source for only one cognitive activity — applying information in new situations. Thus, there is considerable scope in TAFE classes to press students into working things out for themselves.

However, there seemed overall to be a low emphasis on deepening conceptual understanding which could have implications for transfer (Chi, Feltovich & Glaser, 1981). The low emphasis both for organising information and relating it to existing knowledge in practical classes is also of concern in that when learners handle the complexities of real world tasks, their conceptual understanding is deepened (Gott, 1989). If TAFE students' perceptions of a low emphasis on the organisation and linking of concepts is correct, especially in theory classes, then there is scope for improving the learning experiences, perhaps by increasing the diversity of complex tasks.

Theory and practice

Significant differences across theory and practical classes are given in Table 13. Although differences are not replicated across courses, there is some confirmation of the relative teacher-centredness and emphasis on information-giving in theory classes, found in Study 1. It is surprising that there seems to be relatively little use of manuals in practical sessions.

TABLE 6.12: Regression of Learning Sources (Predictor Variables) on each Cognitive Activity (Dependent Variables)

Dependent and significant predictor variables	Cumulative R^2	Degrees Freedom	F	Prob
Learning new information				
From the teacher	.22	1,208	58.3	.0001
Learning to organise information better				
From other students	.05	1,206	10.7	.0012
From the teacher	.08	2,205	9.2	.0002
Learning to apply information in new situations				
From oneself	.04	1,206	9.5	.0024
From other students	.08	2,205	8.3	.0003
From the teacher	.11	3,204	8.3	.0001
Learning to relate new information to things you already knew				
From the teacher	.10	1,208	22.1	.0001
From oneself	.17	2,207	21.3	.0001
Learning about how to do new things				
From the teacher	.13	1,208	31.6	.0001
From oneself	.17	2,207	21.0	.0001
Learning new skills				
From the teacher	.10	1,208	22.1	.0001
From oneself	.12	2,207	13.6	.0001
Learning to relate new skills to things you could do already				
From the teacher	.03	1,208	6.7	.0104
From oneself	.06	2,207	6.6	.0016
Learning to apply skills and information to new problems				
From the teacher	.07	1,208	16.6	.0001
From oneself	.12	2,207	14.7	.0001
From other students	.15	3,206	12.3	.0001

TABLE 6.13: Significant differences between theory and practical classes in terms of cognitive activities and sources of learning content (Means with standard deviations in brackets) (Study 2)

	Course A		Course B	
	Theory (n=48)	Prac (n=43)	Theory (n=65)	Prac (n=54)
Cognitive Activity				
Learning new information			4.00* (0.81)	3.67 (0.89)
Learning to relate new skills to things you could do already			3.32* (0.95)	3.65 (0.76)
Source of Content				
Teacher	4.35* (0.67)	3.77 (0.95)		
Textbook or manual			3.51*** (0.90)	2.30 (1.3)
Other students	2.73** (0.89)	3.23 (0.84)		

*, **, *** significant at the 0.05, 0.01 and 0.001 levels

Conclusions

These studies have painted a picture of teaching and learning in TAFE colleges, with the following dominant characteristics of theory classes:

- Teacher centredness;
- Whole group work; and
- Presentation of information.

The studies have found that the main differences in activities among settings are between theory and practical classes. Practical classes are more

diverse, involve more teacher interaction with individual students and small groups, and more concerned with:

- Demonstrations;
- Practising specific skills;
- Knowledge about skills; and
- Teacher monitoring.

With the teacher as the main source of learning content and with the dominant emphasis on students' acquiring new information and information about how to perform new procedural tasks, there is less emphasis on the organisation of information or the relating of new procedures to existing procedures. Practical classes have a low emphasis on relating new information to existing knowledge, and both theory and practical classes have a low emphasis on organising information.

It seems, then, that there is scope, especially in theory classes, to reduce teacher centredness and to transfer learning responsibility more to students in order to develop their higher order cognitive processes. This could be achieved by pressing students into dealing, on their own, with a larger variety of complex situations and problems, varying the kinds of problematic tasks and explicitly reflecting on the differences among problems and the appropriate procedures for their accomplishment. The effect would be to develop higher order procedures, deeper conceptual understanding and the associations among them (Perkins & Salomon, 1989), which are required for adaptability in the face of change.

In practical classes, there is already a greater diversity of teacher actions, more focus on individual and small group work, more use of concrete materials in instruction and more monitoring by the teacher. Thus there is scope for using some existing aspects of the learning setting, more deliberately, to develop adaptability. Teachers need to refrain from completing difficult tasks for students and from engaging in discourse which supplies answers directly for students. Rather they should assist students to evaluate their own problem-solving strategies and to develop conceptual understanding.

In summary, to achieve greater adaptability, it is suggested that a greater emphasis on variety of activity in connection with real world tasks is

needed so that the deepening and organisation of concepts is promoted. As well, students need to be pressed more into working things out for themselves. Classes need to more student-centred and more resource-centred, more concerned with student problem-solving, more concerned with a deepening of conceptual understanding by building links among concepts and more concerned with building links among conceptual understanding, practical skills and problem-solving strategies. Concrete materials could be used more in theory classes so that concepts are more functionally embedded and so that learners may find them more meaningful.

These studies were undertaken prior to the introduction of Competency-Based Training (CBT). With CBT, it is expected that there will be a reduced emphasis on theoretical classes in TAFE, and from the results of our studies, this could be an improvement.. However, care will need to be taken to move not just towards more practical classes, but to improve these practical classes by placing greater emphasis on the development of higher order cognitive processes and deep conceptual understanding. There are considerable challenges here for the CBT teacher. For example, how does one build in variety and problem-solving when the curriculum pre-specifies a set number of well described tasks? How does one engender, in learners, a value for deep conceptual understanding, when all assessment is performance-based? The design of learning tasks and assessment tasks will be crucial if CBT is not to replace expertise with the abilities of TAFE graduates to perform routine tasks and groups of tasks.

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7 Measuring the press for skill development

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Abstract *This chapter discusses the concept of cognitive holding power and its two dimensions: first order cognitive holding power and second order cognitive holding power. The theories and concepts underlying the development of the instrument are explained. Studies which involved using the instrument in a variety of theory and practical classes in TAFE colleges are discussed. The instrument is robust and performed well across different settings. The main factor influencing cognitive holding power is the teacher. It is concluded that the instrument is useful in undertaking research on learning in vocational education settings and that the concepts are helpful for designing learning tasks for the accomplishment of different learning goals.*

Introduction

In Chapter 1, it is argued that technical expertise involves the coordination of a number of different kinds of knowledge — the specific skills that are needed to perform known tasks (specific or first order procedures); the more general skills that enable the interpretation of new and unfamiliar situations, including the problem-solving strategies applied to these situations and the evaluating skills needed to monitor progress in solving problems (higher, general or second order procedures); and the conceptual knowledge needed for understanding various situations, often at different levels of abstraction (propositional or declarative knowledge). These different kinds of knowledge are represented in memory as different cognitive structures. It is also argued in Chapters 1, 3 and 6 that the learning setting, itself, can press learners into engaging in different kinds of cognitive activity. In this chapter, an instrument is presented and discussed which enables the measurement of the extent to which learners perceive that they are being 'pressed' into using specific (first order) procedures or

higher (second order) procedures. The results of using the instrument in various TAFE settings are discussed.

Influence of settings in activating different cognitive structures

The concept of cognitive holding power is developed from theories of learning settings and theories of learning (Stevenson & Evans, in press) as follows. The tendency for a learning environment to facilitate or impede individuals in goal attainment is called *press* (Murray, 1938). The concept of press can be extended to include student perception of the atmosphere of a learning institution (Pace and Stern, 1958). Settings elicit behaviour from participants (Barker, 1978; Stokols, 1977). The behaviour elicited from settings can be attributed to the participants' cognitive appraisal of the environment, leading to efforts to adapt to the setting and cope with it (Moos, 1979). Kounin and Sherman (1979) referred to the demands of learning settings as holding power. Thus, a learner in a workshop is likely to engage in different cognitive activity and different behaviour from that in a formally arranged classroom. Learners given problems to work on will engage in different thinking from learners who are taken through problems, a step at a time, by the teacher. Behaviour (and the associated thinking) will be different in a real training restaurant from that in a simulated one located (e.g. within a TAFE college); and both will be different from that in a classroom. These different activities utilise different cognitive (memory) structures.

Let's consider, then, the different kinds of cognitive structures activated. The representation of knowledge (cognitive structures) in memory can be differentiated into *knowledge 'that'* (information, facts, assertions, propositions, etc.) and *knowledge 'how'* (techniques, skills, ability to secure goals, etc.) (Anderson, 1990; Norman and Rumelhart, 1975; Ryle, 1949). Knowledge 'that' is termed propositional or declarative; and knowledge 'how', procedural (Anderson, 1982). Procedural knowledge is the ability to perform an action to secure a particular goal, e.g. Anderson (1990). These two types of knowledge may interact. Procedural knowledge often acts upon propositional knowledge, and propositional knowledge may also act as a filter which determines which procedures become active. Based on the

theories of Anderson (1982, 1990), Scandura (1980, 1981) and Fischer (1980), Stevenson (1986a) has developed a hierarchy of procedures of three orders (Figure 1).

FIGURE 7.1: Orders of procedural knowledge

The *first order* comprises specific procedures which enable the securement of goals through the performance of an action. For example, first order procedural knowledge includes knowledge of how to hammer a nail, change a tyre on a car, install a standard window in a frame, turn a piece on a lathe, paint a wall — providing that such tasks have been encountered many times before and the procedures have become automatic.

Second order procedures achieve more general purposes by operating on specific procedures when immediate action goals cannot be fulfilled. They enable such actions as relating, combining, and modifying specific procedures so as to produce new procedures which can handle unfamiliar situations. Second order procedures include knowing how to interpret unfamiliar situations, to search for and select appropriate first order procedures, to solve problems, and to use procedural and propositional knowledge in the acquisition of new skills. Concrete examples include installing a new kind of window in an unusual frame, designing a plan for

a new house to meet a client's requirements, cutting hair to a new style, developing a new strategy for installing plumbing in a high rise building or an experienced turner learning a new skill of Computer Numerical Control Machining.

It has been argued (Stevenson, 1986b) that engagement in learning activities which demand the use of second order procedures assists students in achieving *far transfer* (Mayer, 1974; Royer, 1979), that is, transfer where the learner perceives no clear similarity between the original learning and the transfer tasks. Second order procedures can be likened to Sternberg's meta-components of intelligence (Sternberg & Davidson, 1989), which are involved in 'defining the problem, setting up a strategy to solve the problem and monitoring the consequences of one's problem solving' (p.23).

The *third order* comprises cognitive procedures which achieve overall control of cognition and switch cognitive activity between orders. This third order is variously called a flow of control (Anderson, 1982), a goal switching mechanism (Scandura, 1981), control through procedures (Fischer, 1980), and executive control (Evans, 1991a). In addition to these control functions, propositional knowledge is used in the control and monitoring of first order, or specific procedures, and higher order procedures are elicited when task feedback indicates a problem state (Evans, 1991a; Evans & Butler, 1992). Third order procedures (executive strategies) identify task or situation requirements, set goals, select lower order procedures and propositional knowledge, and evaluate progress towards goal attainment. These procedures activate the use of other procedures and propositional knowledge to modify, combine and control first order procedures to achieve specific goals.

For example, consider a landscape gardener working out a plan for landscaping a sloping allotment. The gardener would not be able to merely execute a number of already developed specific procedures to achieve this goal. Each site would present a different problem. Firstly, the task would be recognised as problematic and third order procedures would switch cognition to the use of second order problem-solving procedures and propositional knowledge to classify the type of problem and to find first order procedures suitable for use in applying to aspects of the problem. Second order procedures may divide the problem up into sub-problems, each related to an overall understanding of the task e.g. drainage problems,

screening problems, problems concerned with the suitability of different plants to the aspect of the site, space problems in the use of space, aesthetic problems. Some sub-problems may be immediately solvable through use of existing first order procedures e.g. installing drainage. The kinds of sub-problems chosen would depend on how the individual gardener understands landscape gardening. As planning proceeded, the gardener would use second order evaluative procedures to monitor the success of second order problem-solving procedures in applying novel sequences of first order procedures to aspects of the overall problem, and third order procedures would activate the use of propositional knowledge as feedback on whether the action being undertaken was consistent with conceptual understanding of the task. For example, the gardener may find that one approach to screening was inconsistent with aesthetic considerations and would need to adopt a different strategy in solving the screening problem.

The instrument described here measures the effect of the learning setting in activating the execution of first and second order procedures. It is assumed that third order procedures activate all cognitive activity, switching activity between first and second orders (Stevenson, 1986a), and activating appropriate propositional knowledge (Evans, 1991a), and are not, directly, the subject of this research.

Cognitive holding power

Cognitive holding power (CHP) is defined as the press from the setting for students to engage in first or second order cognitive processing. Tasks set for learners are interpreted by the learners, themselves, and the tasks in which they actually engage determine what and how much they learn (Posner, 1982). A task can be thought of as consisting of a goal and a set of operations necessary to achieve that goal (Doyle, 1979; Posner, 1982). The cognitive holding power of an environment refers to the extent to which the environment presses students into utilising different categories of cognitive procedures in handling the tasks in which they engage. Thus, in seeking to develop a learner's ability to use second order problem-solving procedures, one could design learning tasks that require the use of such procedures. An example would be to ask students to diagnose a fault in a motor vehicle. The teacher could present the faulty vehicle (or a case study with the symptoms made explicit) and ask learners to determine how they would

work out the cause of the fault. This could be done individually or in groups and the strategies formed by individuals analysed for their potential in solving this and other kinds of problems found in vehicles. In this case, one would expect to find a high level of cognitive holding power for the use of second order procedures (Second Order Cognitive Holding Power). Consider another example where the goal is for the learner to improve typing speed. In this case the teacher may design learning tasks which involve teacher modelling of techniques, student copying of the techniques and substantial practice in attempting to develop speed. Learners would be developing specific procedures to high levels of automaticity and the learning environment would be characterised by a high level of cognitive holding power for the use of first order procedures (First Order Cognitive Holding Power).

Thus, a learning setting which presses students mainly into the utilisation of specific procedures is one where the environment poses goals for the student which can be achieved through the direct execution of existing specific procedures. Such a setting possesses *first order cognitive holding power* (FOCHP). A learning setting which actively presses a student into the utilisation of second order procedures has *second order cognitive holding power* (SOCHP). Contrasting features of settings with First and Second Order Cognitive Holding Power are summarised in Table 7.1 and explained in the following paragraphs.

Setting characteristics which lead to first order cognitive holding power are those which are concerned largely with the practice of existing specific procedures or are ones in which the teacher, or the lesson, tends to minimise the need for the student actively to combine and modify specific procedures. The students' task are reduced to copying or to the simplest interpretation of information. It is the teacher who takes the responsibility for the second order procedures. The student may be largely unaware of the thinking strategies used in the lesson and may not be responsible for controlling them (cf. Rigney, 1980; Derry & Murphy, 1986). Such activities that tend to short circuit the students' use of second order procedures include copying directly from the teacher, being shown a procedure explicitly by the teacher, being told explicitly what to do, and acting on information, ideas, and judgements of the teacher.

TABLE 7.1: Contrasting features of settings with first and second order cognitive holding power

Characteristics	First Order Cognitive Holding Power (FOCHP)	Second Order Cognitive Holding Power (SOCHP)
Press from setting	Presses students into following instructions or procedures, provided by the teacher, e.g. copying, doing as told, doing as shown, relying on the teacher for ideas	Presses students into working things out for themselves, tackling problems, exploring, e.g. finding links, finding out information, checking results, trying out ideas
Examples of teacher activities	Modelling practical tasks, telling, providing information or ideas, instructing, presenting tasks for student practice, showing patterns and relationships, checking results	Posing new and problematic tasks, encouraging students to explore and tackle unfamiliar tasks and situations, providing information only when requested, encouraging students to find patterns and relationships and check their own results against existing knowledge
Examples of student activities	Performing tasks demonstrated by the teacher, following sets of written or oral instructions, relying on the teacher for new ideas and procedures, executing plans provided by the teacher, relying on the teacher for establishing connections and for confirming results, passively accepting new information and procedures, accepting results of activities	Interpreting new situations, making plans, solving new problems, relating existing and new knowledge, generating ideas, trying out new ideas and procedures, checking the results of new procedures against existing knowledge, monitoring own activities
Cognitive activity	Encoding new propositional knowledge and relationships Encoding new specific procedures	Use of second order procedures for making plans, problem-solving and monitoring Use of propositional knowledge for interpretation of problems, monitoring new procedures, and assessing progress toward goals Active reconstruction of propositional knowledge Second order procedures operating on specific procedures

Such activities may foster the learning of the target first order skills, but not second order procedures. Take for example a teacher demonstrating the dismantling of gear box, step by step, with detailed explanations of each step and ample opportunity for learners to copy the individual procedures as the instruction proceeds. This setting would have high first order cognitive holding power. Similarly, there would be a high level of first order cognitive holding power in a theory class where the instruction consists of a teacher explaining the types of scalp diseases that hairdressers might encounter.

A setting with high second order cognitive holding power is defined as one which poses goals unfamiliar to the student, and elicits the execution of second order procedures to interpret the situation and to deal with the associated problems. Such a setting promotes the use of second order procedures and impedes the achievement of goals through only the direct application of specific procedures nominated by the teacher. Second order procedures are used to make links between the features of the setting and existing knowledge, to generate ideas, to try out and test problem-solving strategies, to monitor the effectiveness of approaches, and to check results. Selection, organisation, combination, modification, and application of sets of specific procedures would be achieved through the learners' active use of second order procedures. The trialing of novel combinations of specific procedures and the monitoring of strategies for attacking the situational problems would also be accomplished by second order procedures activated as a result of the switching function of third order executive procedures. Such a setting is conceived as possessing a high level of second order cognitive holding power, which encourages students to confront problems and practise the assembly of new sets of specific procedures. The utilisation of second order procedures would be transferable to other problematic situations and would therefore enable adaptation. For example, a class where learners are given gear boxes to dismantle and information from the manufacturer about maintenance procedures, and asked to proceed to dismantle the gear boxes would have high second order cognitive holding power. A theory class where learners examine slides of diseased scalps and try to determine the causes by relating features of the scalps to knowledge of diseases, and evaluating alternative diagnoses, would have high second order holding power.

Items of the cognitive holding power questionnaire

Three aspects of cognitive holding power can be distinguished: the teacher may encourage an activity; the learner may feel impelled or have agency to undertake the activity (Evans, 1991a), or the learner may actually undertake the activity. Therefore, three basic forms of wording are used for items, as follows:

- The teacher encourages students to (undertake an activity) (TE)
- I feel I have to (undertake an activity) (IF)
- I (undertake an activity) (IU)

The symbols TE, IF, IU are used subsequently to designate the three types of phrasing. A range of activities has been chosen for each level, with activity themes expressed by each of the three forms of wording. The basis for activity themes is the extent to which the item is concerned with the effect of the setting in eliciting activation of first order procedures for direct execution or second order procedures for problem-solving. For first order CHP, items involve the following activities: copying from the teacher; being shown a procedure explicitly; being told explicitly what to do; relying on the teacher for information, new ideas, and links between ideas; and accepting the results of activities without question. For second order CHP, the items involve: students' finding out information for themselves; finding links between different topics learnt; trying out new ideas; and checking results, either by asking questions, or making judgements in terms of one's own knowledge. This represents a sample of second order procedures which can be promoted by the learning environment. The first three involve various forms of problem solving in the acquisition of propositional knowledge. The last is an aspect of monitoring procedures by checking propositional knowledge. The wording of items is given in Table 7.2 and classification by CHP level and activity is given in Table 7.3. Each item is a Likert scale with five response values (1 = never, 5 = always).

TABLE 7.2: Wording of the thirty items

Item Position*	Item Wording
9	The teacher encourages students to copy what he (she) does.
6	I feel I have to copy what the teacher does.
20	I copy what the teacher does.
26	The teacher encourages students to do their work as they are shown.
17	I feel I have to work exactly as shown.
30	I work exactly as shown.
18	I rely on the teacher to show me the links among things.
16	The teacher encourages the student to do what they are told.
24	I feel I have to do what the teacher tells me.
5	I let the teacher tell me what to do.
8	I get all my information from the teacher.
28	I rely on the teacher for new ideas.
23	I accept my results without question.
14	I do what I want to do.
25	I do things my own way.
15	The teacher encourages students to find out things for themselves.
4	I feel I have to find out information for myself.
27	I find information for myself.
3	The teacher encourages students to find the links between the things they know.
22	I feel I have to find links between the things I learn.
13	I find links between the things I learn.
29	The teacher encourages students to check their results against things they know.
12	I feel I have to check my results against things I know.
7	I check my results against things I know.
21	The teacher encourages students to ask questions to check their results.
10	I feel I have to ask questions to check my results.
1	I ask questions to check my results.
11	The teacher encourages students to try out new ideas.
2	I feel I have to try out new ideas.
19	I try out new ideas.

Note * The numbers refer to the positions of the items in the questionnaire

TABLE 7.3: Classification of items by cognitive holding power (CHP) level, activity and wording

CHP Level	Student activity	Item Number (See Table 7.2)		
		Teacher encourages	I feel I have to	I undertake
1	Copying from teachers	9	6	20
1	Being shown explicitly	26	17	30, 18
1	Being told explicitly	16	24	5, 8, 28, 23
2	Permissive / Autonomous			14, 25
2	Find information	15	4	27
(1)*	(Teacher tell information)			(8)
2	Find links	3	22	13
(1)	(Teacher show links)			(18)
2	Check results with own knowledge	29	12	7
2	questions to teacher	21	10	1
(1)	(Accept results)			(23)
2	Try out ideas	11	2	19
(1)	(Rely on teacher for ideas)			(28)

Note * Items in parentheses are cross-classified

Reliability and validity of the cognitive holding power questionnaire (CHPQ)

The reliability and validity of the CHPQ in school and higher education settings have been reported elsewhere (Clark & Dart, 1991; Stevenson, 1992). To study the reliability of the instrument in TAFE colleges, three studies have been undertaken in TAFE colleges as given in Table 7.4. In these studies the two dimensions of CHP (FOCHP and SOCHP) were virtually un-correlated, with factor correlations of .14, .18, and .14 for groups A, B, and D respectively. For the combined data (n = 706), the two dimensions explained 29% of the total variance. Reliability was calculated as Cronbach's α and found to be acceptable (Table 7.5).

TABLE 7.4: Groups of students studied in TAFE colleges

Group	Classes
A:	278 students in 22 different classes across all courses at a single College of TAFE (trade apprenticeship courses, business courses, and advanced level courses in trades, business studies, and electronic data processing)
B:	Seven groups of automotive, fitting and machining students in two colleges each taught three times by two teachers (automotive students in one college taught by only one teacher) (321 observations).
C:	107 students in six classes undertaking welding and electrical courses in three colleges.
D:	Groups A, B and C combined (49 classes involved 706 observations).

TABLE 7.5: Reliabilities of Dimensions by Group

Group	FOCHP Mean	FOCHP Alpha	SOCHP Mean	SOCHP Alpha
A	3.0	.85	3.3	.77
B	3.3	.85	3.3	.87
C	3.2	.82	3.3	.76
D	3.1	.86	3.3	.82

Two studies of validity in TAFE colleges have been undertaken. In the first study, teaching in twenty-seven classes of students in automotive, fitting and machining and butchery students in three colleges was video-taped and the variables coded, every minute, according to whether activities were initiated by the teacher or students, whether activities consisted in presentation or elicitation, the size of the group involved in activities and the nature of the cognitive structures involved (See Chapter 6). Correlations of CHP with the number of minutes devoted to each video-recorded variable are given in Table 7.6 (Stevenson & McKavanagh, 1991:22). It was found that SOCHP is associated with student initiative, students working individually with the teacher and teacher monitoring; FOCHP, with

presentation but not elicitation, provision of information about how to carry out procedures, but not the use of higher procedures.

TABLE 7.6: Correlations of cognitive holding power scales with observed classroom variables (N=27)

Observed Classroom Variables		FOCHP	SOCHP
Action —	Diversity	0.13	0.39*
	Presenting	0.42*	-0.40*
	Eliciting	-0.56**	0.36
	Teacher initiating	-0.12	-0.59**
	Student initiating	-0.05	0.60***
Group size —	Whole group	-0.05	-0.42*
	Small groups	-0.32	0.01
	Teacher with one student	0.32	0.52**
Materials —	Written materials	-0.22	-0.17
	Visual images	0.28	0.13
	Concrete materials	0.09	0.36
Content —	Information	-0.44*	-0.38
	Knowledge about how	0.39*	0.14
	Specific procedures	0.28	0.11
	Higher order procedures	-0.48*	0.12
	Monitoring	0.25	0.38*

* = significant at .05 level; ** = significant at .01 level; *** = significant at .001 level

Analyses of variance (Table 7.7) were conducted to confirm the expectation that First and Second Order Cognitive Holding Power could be attributed to the teacher, rather than such possible alternatives as the teacher's level of experience, the college, the trade area, theory/practice or pre-vocational/apprenticeship. Only main effects were analysed. The teacher had the greatest influence on Cognitive Holding Power, accounting for 16% of the variance in FOCHP and 15% of the variance in SOCHP. The trade area and the college also contributed substantially and, for SOCHP, practical classes appeared to contribute more to SOCHP than theory classes. The

results suggest that, apart from the cognitive holding power created by the actions of individual teachers, it is the nature of workshop activities, especially for apprentices, that create SOCHP. These results provide more confirmation of the validity of the two scales in measuring cognitive holding power in TAFE classes.

TABLE 7.7: Analysis of Variance of First and Second Order Cognitive Holding Power (Main effects only)

(a) First Order Cognitive Holding Power

Independent Variables	Statistics			
	R^2	F	df	Direction of Effect
Teacher	0.157	7.00***	9,339	
Level of Experience	0.013	4.58*	1,347	No effect
College	0.067	12.38***	2,346	A>B>C
Trade area	0.113	22.14***	2,346	1>2>3
Theory or Practice	0.000	0.00	1,347	T=W
Pre-vocational or Apprenticeship	0.017	6.01*	1,347	P>A

(b) Second Order Cognitive Holding Power

Independent Variables	Statistics			
	R^2	F	df	Direction of Effect
Teacher	0.138	6.1***	9,340	
Level of Experience	0.001	0.37	1,348	E>N
College	0.066	12.36***	2,347	A>B>C
Trade area	0.064	11.89***	2,347	2>1>3
Theory or Practice	0.052	18.98***	1,348	W>T
Pre-vocational or Apprenticeship	0.026	9.15**	1,348	A>P

Notes * = significant at .05 level
** = significant at .01 level;
*** = significant at .001 level
A, B, C are different colleges
1, 2, 3 are different trades
E = Experienced, N = Little Experience
T = Theory classes, W = Workshop
A = Apprenticeship, P = Pre-vocational

In the second study (electronic process control and carpentry and joinery), the effects of sources of learning content (the teacher, other students, workbooks and manuals or working things out for oneself) on First and Second Order Cognitive Holding Power were examined. The sources of content were identified using a Knowledge and Learning Questionnaire administered to students (See Chapter 6). The effects were analysed through multiple regressions (maximum R-square improvement method) (Table 7.8). Working things out for oneself had a substantial influence on SOCHP followed by the teacher and other students. For FOCHP, the teacher and other students had more influence than working things out for oneself. These results add more weight to the validity of the instrument in measuring these dimensions of learning environment in TAFE classes.

TABLE 7.8: Regression of sources of learning on first and second order cognitive holding power

(i) First order cognitive holding power

	Cumulative R^2	Degrees Freedom	F	Prob
Learning from teacher	.038	1,187	7.42	.0071**
Learning from other students	.077	2,186	7.76	.0001***
Working things out for oneself	.098	3,185	6.67	.0003***

Note: Work books and manuals as a source was not significant for either analysis

(ii) Second order cognitive holding power

	Cumulative R^2	Degrees Freedom	F	Prob
Working things out for oneself	.12	1,194	26.0	.0001***
Learning from the teacher	.17	2,193	20.3	.0001***
Learning from other students	.22	3,192	21.9	.0001***

Note: Work books and manuals as a source was not significant for either analysis

Conclusions

An instrument is available for measuring first and second order cognitive holding power in vocational education learning settings. The instrument is both valid and reliable. The results of the present studies suggest that, while students' perceptions of first and second order cognitive holding power are not mutually exclusive setting characteristics, such perceptions are independent and practically un-correlated across settings, and that each comprises a correlated set of activity themes. Further, the perceptions of either first or second order CHP hold across different activities and embrace teacher encouragement, feelings of press, and actual behaviour.

As argued in Chapter 1, expertise in the work place requires conceptual understanding, first order procedures and second order procedures. The measurement of CHP has implications for research and teaching. As discussed in Chapter 1, there has been a variety of approaches to the development of expertise. For example, teaching methods which emphasise discovery develop greater learner independence in handling the unfamiliar problems required in far transfer (Stevenson, 1986b). On the other hand, reliance on means-ends strategies of discovery can interfere with learning, and it has been demonstrated that well-structured worked examples reduce demands on working memory and facilitate the development of problem-solving skills (Ward & Sweller, 1990). These apparently contradictory findings can be reconciled by differentiating transfer problems which involve re-application of strategies learned in training, but with new move sequences (specific procedures), from those which require the discovery of a new strategy (McDaniel & Schlager, 1990). Teaching methods entailing discovery of strategies (second order procedures) are better than provision of methods (first order procedures) when a new strategy has to be generated to solve a transfer problem (McDaniel & Schlager, 1990).

The measurement of CHP in research would contribute to an analysis of the results, answering questions concerning the role of the learning setting in developing abilities for different kinds of transfer. The concepts explained in this chapter indicate that the teaching of problem-solving through worked examples would be characterised by learning environments of high first order CHP, appropriate for near transfer. On the other hand, teaching through discovery would involve high second order CHP, appropriate for far transfer. Consideration of relationships between CHP and learners'

abilities to transfer within and beyond specific content areas may also contribute to understanding the extent to which problem-solving ability is restricted to particular domains of knowledge (Glaser, 1984; Royer, 1986).

Measurement of cognitive holding power can help to increase teachers' awareness of the kinds of cognitive activity in which learners are engaging and the kinds of cognitive structures which are being developed. Such awareness will enable evaluation of instructional strategies and assist further instructional design. The activation of different kinds of cognitive activity is assumed to be mediated by the tasks set for students. Teachers need to consider the tasks which they design for student work and analyse the tasks in terms of the goals and operations necessary to achieve that goal (Doyle, 1979; Posner, 1982). Where the goals are problematic and require the use of problem-solving, interpretive and evaluative procedures, this press will be manifest in second order cognitive holding power. Where the learning tasks pose goals for the student which can be achieved through the direct execution of existing specific procedures, this will be measurable as first order cognitive holding power. The challenge in teaching for far transfer or adaptability is to increase levels of second order cognitive holding power. The challenge in teaching for automaticity in performing routine skills is to create a high level of first order cognitive holding power.

Increasingly, it is being recognised that frequent qualitative changes will continue to occur in the nature of work. Accordingly, adaptability will become an even more valuable attribute in the work place. For these reasons, it is argued that vocational educators give explicit attention to improving vocational education and training through the generation of more second order cognitive holding power.

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8 Pressing TAFE learners into far transfer within a CBT framework

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Abstract *Competency-based Training (CBT) has been introduced by governments in an effort to achieve a 'globally competitive' country. The reform has preceded research into its effectiveness. For instance, to date, the introduction of competency based curricula at the Queensland College of Tourism and Hospitality has not been subject to a great deal of scrutiny of the educational outcomes. The purpose of this study is to examine the kinds of cognitive processes students studying in the Associate Diploma of Business (Travel) course are actively utilising, and the effects on the success rate in completing a transfer task. This course is documented in terms of learning outcomes in line with the CBT Agenda. The sample was a group of sixty (60) first semester students in a ticketing subject. The Cognitive Holding Power Questionnaire (see Chapter 8), which measures the effect of the learning setting in activating different levels of procedural knowledge was used to examine learning environments in these classes. It was found that classes differed significantly in second order cognitive holding power (SOCHP), and there was some limited evidence for the predicted relationship between SOCHP and performance on a transfer task.*

Introduction

Wirth (1993) has noted that we are well into the beginning of the new post-industrialism which involves three significant developments:

1) the electronic computer revolution;
2) the emergence of a competitive global market; and
3) the prospect of serious ecological damage.

He believes that as we struggle to cope with this new era, two of the major determinants in our lives, education and work, will need to alter. This is

consistent with the government's view that, if Australia is to become competitive in such a global economy, it needs to change its work practices rapidly and improve the skill levels of its workforce (Dawkins & Holding, 1987). Accordingly, the Federal Government has targeted improvements to, and the expansion of, industry training as a key component of its reform agenda.

Over recent years, Competency-based Training (CBT) has been introduced into the Australian TAFE system at a rapid rate. The speed of its introduction has meant that little debate or research by educators has taken place. Its premises are not argued from learning theory; yet it is directed explicitly at learning outcomes. Learning settings are being transformed as teachers focus on outcomes in an attempt to help students to become competent. The effects of CBT on education in general (e.g. Collins, 1993; Porter, Rizvi, Knight, & Lingard, 1992) and on learning in vocational education in particular (e.g. Stevenson, 1990a,1991a,1992a,1992b,1993) are starting to receive attention, with concerns being raised as to its merit.

Contemporary cognitive research provides evidence that classroom environments can be created in vocational education with different cognitive demands on learners, and that those with higher demands can assist students to become less dependent when mastering a new, but related, technique (Stevenson, 1986a,1986b,1991b) (See also Chapter 7).

If skill levels of the Australian workforce are to improve significantly, teaching in TAFE needs to be directed not only at the development of immediate competence on known tasks, but also competence in addressing new and unfamiliar problematic situations. Although the adoption of CBT has raised concerns amongst TAFE teachers about the effects on learning, in this paper it is argued that, within the CBT paradigm, teachers can, nevertheless, improve the learning of their students through attention to the design of the learning setting.

CBT has been implemented at the College of Tourism and Hospitality. To facilitate its implementation, delivery methodologies have been adapted from other learning contexts, as a convenient way of supporting teaching staff. Little empirical, and no theoretical research has taken place to support its implementation. This study was aimed at improving teaching practice, through examination of the impact of learning settings on the cognitive

processes of a group of students participating in a new curriculum in Travel Studies, formatted in CBT terms. The Cognitive Holding Power Questionnaire (See Chapter 7), which measures the effect of the learning setting in activating different levels of procedural knowledge, was used to gather data about the setting, and to confirm the cognitive processes used by the students.

This Chapter:

- examines the implications of the government's CBT agenda for teachers, curriculum development and learning in TAFE classes;
- examines the problem of transfer in vocational education from a cognitive perspective; and
- presents the results of an empirical study on the relationship between cognitive demands placed on the learner and their performance on a transfer task.

The chapter commences with an examination of the federal government's adoption of CBT because it is central to understanding the negativity surrounding its implementation. It is hoped that examination of its reported shortcomings will provide teachers with reference points from which to reflect upon their current practices in a CBT setting. The chapter then outlines some significant advances in cognitive theory over the last decade, which assist with an understanding of the cognitive processes that encourage learners to develop those skills that are critical for participation in a modern workforce, and are also conducive to lifelong learning. Finally the chapter reports research which tests an hypothesis, derived from the skill formation literature, that even within a CBT framework, teachers can improve the effectiveness of the learning setting.

The Government's CBT agenda

The intervention of the Federal Government into Australian educational practice, recommended by many reports (e.g. Dawkins and Holding, 1987; Dawkins, 1988; Finn, 1991; Mayer, 1992; Morrow, 1992; VEETAC, 1992), signals a period of educational change that seems to be driven largely by

social and economic agendas. The TAFE environment is currently experiencing a period of vigorous attention where the National Framework for the Recognition of Training (NFROT) (The National Training Board, 1992) requires that all new curricula be developed in a CBT format (i.e. with explicit connection to industry standards). The Federal Government has established the National Training Board to co-ordinate the development of these national standards, expressed as units and elements of competency. Advice is drawn from competency standards bodies (CSB's) representing such bodies as each industry's peak bodies, and National Industry Training Advisory Boards (ITAB's). Through State accreditation agencies, the inclusion of learning outcomes related to these competencies are mandated for any curriculum.

This intervention is occurring despite the fact that nearly two decades of scholarship, including theoretical critique and empirical research originating in philosophy, psychology, linguistics, education, and sociology, argues in various ways that the competency paradigm has not and probably will not 'improve learning' in most of the educational contexts where it has been applied (Jackson, 1992). The persistence of CBT as a framework for education and training provision, in spite of the criticism, is considered by Jackson (1992) to be connected to its use by government as an instrument of economic management of vocational education. Making educators accountable is an increasingly popular tool for administrators in the present political and fiscal climate. For this purpose, Maclure (1991) describes CBT as a seductive tool, despite its recognised tendency to be 'narrow' and 'reductive' and to generate opposition from teachers.

Teachers lacking experience with the principles and mechanics of the competency movement complain of overwhelming jargon and time consuming preparation and testing of competencies (Jackson, 1992). Jackson claims that teachers feel that they are no longer free to determine either the ends or the means of the instructional process. That is, they perceive that their role is instead a support function, as a facilitator subordinated to the goals and objectives which are determined by others. Teachers feel that they no longer manage the teaching and learning environment, and therefore the impact CBT has on it.

The model of change adopted for implementing CBT

The perspective of many TAFE teachers, is that the implementation of CBT curricula has been through legislation rather than by legitimation. Thus, where this educational reform has got it wrong is through not recognising that autonomous, self-determining individuals (teachers) must be tightly coupled in a co-operative venture with the system (McMeniman, 1991). McMeniman argues that there must be shared understanding of how critical the individual teacher is to the process of change. Teachers change their managerial and instructional strategies by choice, and there must be a recognition by policy-makers that self-determination is important in change (Fullan, 1991). Fullan (1991) has carried out extensive research into educational change at the regional and national levels in the United States, and argues that 'Statewide intensification systems tightly designed to align curriculum, teaching, and student performance cannot work without reducing the educational enterprise to a low common denominator'. The alternative, he suggests, is to draw upon the innovation paradigm (i.e. that innovations are less a source of rational ideas, and more an array of possibilities) and the notion of alliances, to provide greater power, both of ideas and of the ability to act on them. This approach would recognise that teachers remain the managers of the classroom, despite the political givens of CBT, and, hence, play a critical role in creating and enhancing the learning setting.

The imposition on teachers of competency-based training, using a top-down methodology, prevents teachers from developing a sense of ownership. While the approach allows teachers and colleges to determine their own teaching methods, the all important *purpose* of education still remains the property of legislators who currently hold a view that educational outcomes can somehow be prescribed in advance, as outcomes which equate to a set of 'standards'. The lack of involvement of teachers in the introduction of CBT, other than being left to implement it, has created a negative, or at best confused, teaching and learning environment for many teachers (Funnell, 1993). The dis-enfranchisement felt by many teachers impacts negatively on their classroom setting.

As argued above, despite the political givens of CBT, it is teachers who remain the managers of the classroom and play a critical role in creating and enhancing the learning setting. However, while the CBT paradigm

focuses on learning outcomes (competencies), it needs to be recognised that it does not prescribe the teaching methodologies to be adopted. Yet, often, CBT implementation has consisted in a direct adoption of methodologies from other learning contexts, rather than in any real attempt to integrate an outcome emphasis into a teacher's own teaching and learning setting.

The changing concept of competency

The architects of CBT insist that it is not Taylorist or behaviourist (Carmichael, 1991). Earlier attempts appeared to be extremely narrow and explicitly behaviourist in their focus (Stevenson, 1991a). Moreover, current assumptions about underlying conceptual and procedural knowledge in levels of the Australian Standards Framework still need questioning (Stevenson, 1992a,1992b,1993). However, the concept of a competency continues to unfold. For instance the Mayer Committee (1992) takes an explicit cognitive view of competence as opposed to the neo-behaviourist view implicit in earlier discourse on the subject. From a cognitive perspective this is a major improvement (Stevenson, 1992a).

However, the lack of input from educators in formulating policy and practice is also starting to show up as a glaring omission, now that implementation questions are being addressed. The identification of competencies (outcomes) has been dealt with, whilst largely ignoring how students learn, and the learning setting. It is clearly important that the implementation of CBT addresses both the learning environment and the way in which students learn.

The impact of CBT on curriculum development

Curriculum development as advocated for the TAFE sector seems largely to be technical/rationalist in its orientation (Blatchford, 1986; McBeath, 1991). TAFE curricula tend to focus on the *technical* skills that are capable of making students either employable, or more expert in their employment. Stevenson (1990a,1991a,1991b) claims that cognitive and affective objectives are rarely identified, and higher order procedural knowledge is seldom specified. Governmental spokespersons assert that CBT is not neo-behaviourist, and that it accommodates the attributes needed for

adaptability, innovation, interpersonal communication, and higher order thinking (e.g. Carmichael, 1991; the National Training Board, 1992).

Despite these assertions, standards on which CBT curricula are built appear to be concerned mainly with how the learner performs a task, or a complex of tasks, in an approved manner. For example, the National Training Board (NTB) (1991,1992) refers to these skills as:

Task Skills — the requirement to perform relevant tasks (individual tasks);
Task Management Skills — the requirement to manage a group of tasks to achieve overall job function;
Contingency Management Skills — the requirement to respond to breakdowns in routines, procedures and sequences; and
Job/Role Environment Skills — the requirement to respond to general aspects of the work role and the environment, such as natural constraints, working relationships and the work organisation.

This concept of competence connotes convergence of learners towards a standard of performance, an emphasis on cognitive procedures which are executed to achieve predictable goals (competencies), without attention to the manner in which the student might use conceptual knowledge and more general purpose cognitive procedures to solve unfamiliar and unpredictable problems in new or novel ways. Even the 'contingency management skills' seem to connote predictability and the training of learners to handle them in anticipated ways.

Yet, the purpose of learning is the eventual development of the ability to formulate original thought and new knowledge, and to help learners to work out their own understanding, rather than regurgitate the statements of others (Lawson, 1979). It is this longer term goal which may be used to distinguish an 'educational' from a 'training' process. How a person is taught is as important as what is taught, in determining whether such teaching is 'educational' rather than an example of 'training' (Lawson, 1979). A CBT curriculum forces teachers to focus on outcomes (i.e. what the student can do), but largely ignores the knowledge and processes associated with carrying out tasks, particularly the processes involved in getting students to apply known skills to unfamiliar tasks. However, there is still some scope for teachers to re-instate a focus on learning process, albeit within the framework of prescribed outcomes.

The challenge then, is to ensure that, in an educational setting, CBT curricula are developed with a cognitive focus that considers not only the outcome skill but also the development of that skill, as new meaning for the student, and as a basis for autonomous action in unforseen circumstances. This means that teachers need to provide learners with an environment that not only takes account of the competencies described in the curriculum, but also encourages them to become independent learners, become able to generate and try out new ideas, solve problems by interpreting new situations, explore and tackle unfamiliar tasks, and monitor their own activities and progress. These abilities have been referred to in the literature as transfer (e.g. Mayer, 1975; Royer, 1979).

The ability to use existing knowledge in a new way has been termed adaptability, the ability to transfer knowledge from one situation to a new one. The extent to which the new situation differs from the initial learning situation determines the type of knowledge which needs to be transferred. Transfer, itself, has been differentiated in two ways — *specific* versus *non-specific* transfer (Royer, 1979) and *near* versus *far* transfer (Mayer, 1975). By *specific transfer* Royer meant transfer which occurs when the task being undertaken is similar to the task used in the original learning. *Non-specific transfer* occurs when the task is dis-similar to the original task. Mayer's differentiation of *near* and *far transfer* is similar. It indicates when the stimulus complex is either similar to the original learning or somewhat different, respectively. In vocational education it is necessary for students to develop both near and far transfer.

Teaching for far transfer

One of the broad goals of education is to encourage the application and transfer of skills, rather than to provide simple demonstrations of knowledge or competence in the classroom (Paris & Winograd, 1990). Teachers need to make learning sensible and personally relevant for students irrespective of the delivery methodology. That is, learners need to be able to relate new knowledge and skills to existing knowledge and skills, and develop proficiency and the ability to apply this knowledge to new situations. An understanding of how students acquire skills and the cognitive structures they employ, is central to teachers' development of appropriate learning settings. The following paragraphs contextualise the

current study in terms of theories relating to skill acquisition, the cognitive structures needed for far transfer and the instructional design needed to develop these structures. In the following section, the contemporary literature on skills and their development is examined.

Stages of Skill Formation

Theories relating to the cognitive structures applicable in vocational education have been advanced and refined by a series of authors (Anderson, 1982,1990; Campione and Brown, 1990; Collins, Brown, and Newman, 1989; Scandura, 1981; Shuell, 1990; Stevenson, 1986a,1991b). All of these authors articulate a process of stages through which learners pass as they acquire mastery of skills. These theories are outlined in the following paragraphs. (See also Chapter 3).

Based on the work of Fitts (1964) who identified three stages of skill acquisition, a *cognitive stage*, an *associative stage*, and an *autonomous stage*, Anderson (1982) suggests that the mechanism by which specific skills are developed involves only two major stages, a *declarative stage* and a *procedural stage*. Anderson's theory is based on Ryle's (1949) differentiation between 'knowledge that' and 'knowledge how'. These terms, in current cognitive literature, have the following meanings. Cognitive structures can be differentiated into those which represent knowledge 'that' (information, facts, assertions, propositions, etc.) and those that represent knowledge 'how' (techniques, skills, ability to secure goals, etc.) (e.g. see Stevenson, 1991b). Knowledge 'that' is normally referred to as propositional knowledge while knowledge 'how' is called procedural knowledge.

Anderson argues that, in the initial declarative stage the learner processes instructions and information about the skill. The information is encoded as a set of facts about the skill. He argues that, in the procedural stage, further learning takes place after the knowledge achieves procedural form. There is also further tuning of the knowledge, so that it will apply more appropriately, and there is a gradual process of speed-up. He regards Fitt's associative stage as the process of moving from the declarative stage to the procedural stage.

Similarly, Scandura (1981) argues that learners pass through three stages as they master skills. As *Naive learners* they can combine rules and higher order rules to solve problems. As *Neophytes* they have developed sets of explicit rules they are able to apply. Finally, as *Masters*, they are able to combine rules into more efficient and complex sets which enable them to work on more complex structures. The acquisition of these more efficient rules is described as *automatisation*, in which higher order rules make redundant previous less complex rules.

Sweller (1989) supports such concepts by arguing a set of propositions about the relationships between learning and problem-solving. He argues that problem-solving skill is heavily dependent on an extensive, domain-specific knowledge base. This knowledge base can be specified largely in terms of *schema acquisition* and *rule automation*. He defines a schema as a cognitive construct that permits problem-solvers to recognise problems as belonging to a particular category, requiring particular moves to solutions. He views an automated rule as one that can be used automatically without conscious processing. Similarly, Kotovsky, Hayes, & Simon (1985) suggest that if two rules can be known and understood, but if one can be used automatically while the other requires considerable effort to retrieve and use, then problem-solving would be more easily facilitated by using the automated rule.

Shuell (1990) also suggests that the learner passes through a series of stages or phases during which the learning process and the variables influencing it change systematically. He describes the phases as the *initial*, *intermediate*, and *terminal* phases of learning. During the *initial* phase the learner acquires isolated facts that are interpreted in terms of pre-existing schemata. Gradually the learner begins to assemble these pieces into new schemata providing more conceptual power (*intermediate* stage). Finally the learner attains a level of automaticity in what Shuell describes as the *terminal* phase.

Cognitive structures for far transfer

Thus, in meaningful learning, the learner passes through a series of stages, from knowing virtually nothing about a complex body of knowledge to the demonstration of a highly proficient and automatic mastery in the form of procedural knowledge. As learners progress from initial encounters with

simple facts or skills, the ability to assemble these skills into new schemata increases, until finally they are able to demonstrate proficiency in that skill, in a more-or-less automatic way. However, what is interesting is that, with any new situation, the learner returns to the state of a naive learner and must rely on conceptual understanding and general problem-solving skills (See also Chapters 3 and 4). That is, highly proceduralised knowledge is inadequate in unforseen circumstances. In these situations, the learner must return to conceptual knowledge and general procedural knowledge. Thus, it is this latter knowledge which is needed for far transfer.

Instructional design

Before the evolution of schooling, apprenticeship was the most common method of learning used to transmit the knowledge required for expert practice. A by-product of the relegation of learning to schools is that skills and knowledge have become abstracted from their uses in the world (Gott, 1989) (See also Chapter 2). On the other hand, apprenticeship learning embeds the learning of skills and knowledge in their social and functional context (Collins, Brown and Newman 1989). According to Collins, Brown, and Newnam, apprentices learn through a combination of *observation*, *coaching* and *practice*, or what might be termed from a teacher's point of view *modelling*, *coaching* and *fading*. A key aspect of coaching is the provision of scaffolding, which is support, in the form of reminders and help (See also Chapter 2). Observation also plays a key role in aiding the learner to develop a conceptual model of the target task. Collins, Brown, and Newman (1989) coined the phrase 'cognitive apprenticeship' to refer to the focus of the learning through guided experience on cognitive and metacognitive, rather than only physical skills and processes. They argue that:

> *In cognitive apprenticeships, conceptual and factual knowledge are exemplified and situated in the contexts of their use. Conceptual and factual knowledge thus are learned in terms of their uses in a variety of contexts, encouraging both a deeper understanding of the meaning of the concepts and facts themselves and a rich web of memorable associations between them and problem-solving contexts.* (Collins, Brown, and Newnam, 1989: 457)

Cognitive apprenticeship teaching methods bring these tacit processes into the open, where students can observe, enact, and practise them with help from the teacher and from other students.

Drawing on the work of earlier authors (Barker, 1968,1978; Moos, 1979; Murray, 1938; Pace and Stern, 1958), Stevenson (1990b,1992b) (see also Chapter 7) has developed the Cognitive Holding Power Questionnaire (CHPQ) to measure the extent to which learning environments press learners into different levels of cognitive activity. He has argued that the tendency of a learning setting to press students into using second order cognitive procedures is paramount in their development of the capacity for far transfer skills. He defines *first order procedures* as the automatised procedures which result from progressing through the stages of skill acquisition outlined above. He defined *second order procedures* as those procedures used for more general purposes such as problem-solving, monitoring and new learning, and which operate on first order procedures (Stevenson, 1986a,1991b).

The purpose of the present study was to examine a CBT learning setting to determine the effectiveness of normal classrooms in pressing students into using first and second order cognitive procedures, and the effects on subsequent performance on near and far transfer tasks. The broad question raised is: *Within a CBT framework, can teachers provide learning settings in which students are pressed into the use of second order cognitive procedures, and does this affect their abilities to handle a far transfer task?*

Learning activities that press students to inquire and explore naturally, rather than seek guidance and answers from the teacher, are fundamental for such a setting. Thus, the question examined in this study has been operationalised as:

> *That the greater use of second order cognitive procedures in a class setting will produce a greater success rate in completing a task involving far transfer.*

Empirical study

The following paragraphs describe the study and examine the data.

Sample

The sample for this study consisted of sixty (60) students enrolled in the inaugural semester of an Associate Diploma of Business (Hospitality) at the College of Tourism and Hospitality (COTAH), Brisbane. The course had recently been re-developed in a CBT format. The students were selected by the Queensland Tertiary Admissions Consortium (QTAC), based on their Overall Position (OP) score awarded at the end of twelve (12) years of schooling or a notional OP awarded to mature age entrants. The students were divided into four (4) groups of fifteen (15) named A, B, C, and D. Groups C and D were selected later, due to additional funding being available, and this resulted in these groups being drawn from a lower OP level.

Fifty-two students were used in the research as eight were away from class on the day of the first administration of the instruments. Age and Sex data are given in Tables 8.1 & 8.2.

TABLE 8.1: Age by group

Groups	Mean	Std dev	N
All	20.1	5.3	52
A	21.3	4.6	13
B	22.3	9.0	13
C	18.5	1.5	13
D	18.5	2.0	13

TABLE 8.2: Sex by group

Sex	Group A	Group B	Group C	Group D	Total
Female	13	11	10	11	45
Male	0	2	3	2	7

Of the 52 cases used in the study, 45 were female and 7 male. There has historically been a larger female population attracted to this course. The ages ranged from 17 to 51 years with a mean of 20.1. The spread of ages represents a mix of both immediate post grade 12 and mature age students. Groups A and B have a higher mean age caused by enrolment of university students, whose achievement at university generally translates into higher OP scores when they change courses. Correspondingly, the lower mean age of groups C and D reflects the greater number of school leavers in these groups.

Design of the study

A causal-comparative methodology (Gay, 1987) was adopted for this study in an attempt to establish whether or not students who use second order cognitive procedures in the learning setting perform better at a far transfer task. The independent variable used in the study was the learners' use of first and second order cognitive procedures during learning, as measured by the Cognitive Holding Power Questionnaire. It was assumed that press for cognition at different levels resulted in actual cognition at those levels. The dependent variables were the success rates on an assessment instrument which required the learners to attempt two transfer tasks, one that required the use of specific (first order) procedures (near transfer), and the second requiring the use of general (second order) procedures (far transfer).

The study was undertaken over a four week period in which the knowledge which was the subject of investigation was taught to the students. The same testing instrument was used for both the pre-test and post-test. The pre-test identified any students able to complete the test successfully and they were eliminated from the study. It was also used to determine the gain scores following instruction. The Cognitive Holding Power

Questionnaire was administered at the same time as the post-test to measure the press of the current learning environments. The design of the study is illustrated in Figure 8.1.

Week One		Weeks Two and Three		Week Four
Students	Activity	Activity		Activity
Group A ⟶		Subject material	⟶	
Group B ⟶	Pretest	associated with the	⟶	Post-Test
Group C ⟶		Testing Instrument	⟶	CHPQ
Group D ⟶		given to the students during this period, by teachers teaching in their normal preferred style.	⟶	

FIGURE 8.1: Design of Study

Procedure

The procedures were as follows:

1 Pretest

The students were presented a task sheet and questionnaire. The task sheet posed a question requiring application of propositional knowledge to a routine procedure, as well as a far transfer question that required use of second order (procedural knowledge). For data analysis purposes, those students who were able to complete the far transfer on the first attempt (pre-test) were not used further (n=1).

2 Teaching

A period of two weeks elapsed in which teaching and learning of the content needed to undertake the task was provided.

3 Post-tests

Following the completion of the new theory component, the task was re-administered. The Cognitive Holding Power Questionnaire was also administered to measure the extent to which learners were pressed into using first and second order cognitive procedures during instruction in the class setting.

4 Analysis

The gain score for each question was calculated by subtracting the first score from the second score. Any minus score was treated as zero, or no gain. Differences among groups were analysed.

Instruments

Cognitive Holding Power Questionnaire

The Cognitive Holding Power Questionnaire measures the degree to which the setting presses students into the utilisation of First and Second Order Cognitive Procedures — First Order Cognitive Holding Power (FOCHP) and second Order Cognitive Holding Power (SOCHP). (See Stevenson and Evans (in press) and Chapter 7 for data on validity and reliability). A summary of characteristics of First and second Order Cognitive Holding Power is given in Table 8.3.

Test Questions

The second instrument used in this study was a test instrument prepared by the teacher under the guidance of the author. The instrument contained two questions designed to test ability to use both first and second order cognitive procedures. The two questions were related to the same body of theory used in the teaching of ticketing to Travel Studies students. The face validity of this instrument has been accepted because the teacher is an expert in ticketing.

TABLE 8.3: Characteristics of first order cognitive holding power and second order cognitive holding power (see Stevenson and McKavanagh (1991b).

FOCHP Characteristics	SOCHP Characteristics
Performing tasks demonstrated by the teacher, following sets of written and oral instructions, relying on the teacher for establishing new ideas and procedures, executing plans provided by the teacher, relying on the teacher for establishing connections and for confirming results, passively accepting new information and procedures, accepting results of activities	Interpreting new situations, making plans, solving new problems, relating existing and new knowledge, generating ideas, trying out new ideas and procedures, checking the results of new procedures against existing knowledge, monitoring own activities

The first question required the student to apply a fact in the issue of a bus ticket. Thus, the learner would execute a first order procedure once the fact was recognised as satisfying the condition for executing the action of the procedure.

The second question required a more complex answer which required the student to apply principles to an unfamiliar task. The broader ticketing constructs they were required to consider were:

- general principles relating to refunds within the industry;
- specific principles applying to the currency of a ticket on a broken journey; as well as
- general principles of travel insurance that apply to this problematic case.

Thus, the second order procedures, needed to obtain the correct answer for the second question, required learners to interpret how some general principles of refunds and travel insurance relate to more specific principles on currency of tickets, as they might apply in a problematic situation of a broken journey.

Limitations of the Study

The reliability of the questions on the test paper have not been established, and the validity has not been confirmed. Therefore, one cannot be certain that the gain score can be entirely attributed to the use of second order procedures. Also, it was not possible to assign learners randomly to groups, and learners with different entering characteristics formed different groups. Thus, there are several possible explanations for the findings of the study. Thus it is possible that any differences in cognitive holding power or gain scores may be due to differences in age and previous experience, rather than differences in teaching. Hence, caution is needed in interpreting the findings from this study.

Findings

Table 8.4 provides Mean Scores for each group on FOCHP, SOCHP, Gain Score 1, and Gain Score 2.

TABLE 8.4: Cognitive holding power and gain scores by group

	Means (Standard deviations in brackets)			
	FOCHP	SOCHP	Gain Score 1	Gain Score 2
Group A	41.08 (4.35)	46.92 (7.04)	.69 (.48)	.77 (.83)
Group B	40.69 (6.76)	46.62 (5.09)	.38 (.51)	.54 (.88)
Group C	43.54 (8.02)	46.23 (5.33)	.38 (.51)	1.15 (1.07)
Group D	41.77 (6.26)	47.31 (6.32)	.62 (.51)	1.54 (.78)

ANOVAs were performed on First Order Cognitive Holding Power (FOCHP) and Second Order Cognitive Holding Power (SOCHP) by Group, in order to establish if the differences across groups were significant (Table 8.5). There were no significant differences in FOCHP, whilst the differences in SOCHP were significant at the .05 level. A Scheffe test failed to identify which groups were significantly different. ANOVAs were also performed on Gain Score 1 and Gain Score 2 by Group in order to establish if any significant relationship existed (Table 8.6). Gain Score 1 was not significantly different across groups, while differences in Gain Score 2 (far transfer) were significant at the .05 level. The far transfer gain scores were higher for the (lower OP) school leaver groups (C&D) than the (higher OP) university entry groups (A&B) (Table 8.4).

TABLE 8.5: ANOVAs of first and second order cognitive holding power by group

(a) Second order cognitive holding power

Source	d.f.	Sum of squares	Mean squares	F	Prob.
Between groups	21	40.6	1.9	2.37	0.015
Within groups	30	24.5	0.8		
Total	51	65.0			

(b) First order cognitive holding power

Source	d.f.	Sum of squares	Mean squares	F	Prob.
Between groups	23	23.9	1.0	0.71	0.800
Within groups	28	41.1	1.5		
Total	51	65.0			

TABLE 8.6: ANOVAs of gain scores 1 & 2 by group

(a) Gain score 1

Source	d.f.	Sum of squares	Mean squares	F	Prob.
Between groups	3	0.98	0.3	1.31	0.283
Within groups	48	12.00	0.3		
Total	51	12.98			

(b) Gain score 2

Source	d.f.	Sum of squares	Mean squares	F	Prob.
Between groups	3	7.54	2.5	3.14	0.034
Within groups	48	38.46	0.8		
Total	51	46.00			

To investigate the relationships among dependent and independent variables further, the groups were combined and a linear multiple regression was conducted using the gain scores as the dependent variable (Table 8.7).

The independent variables were Pre-test Question 1, Pre-test Question 2, FOCHP, SOCHP and Group. For Gain Score 1, no significant relationships were found. However, for Gain Score 2, the results were as given in Table 8.7.

Thus, Pre-test Question 2, Group, FOCHP and SOCHP were found to contribute significantly to the far transfer gains of instruction. Collectively they were able to explain 31.2% of the variance of Gain Score 2. However, 13% of the variance was explained by the pre-test performance on the transfer task. Thus, one rival explanation for the results is that the pre-test may have sensitised the learners to the nature of the post-test.

TABLE 8.7: Linear multiple regression table — extract for gain score 2

Step	Independent Variables	R^2	ΔR^2	F	P
(1)	Question 2 (first Administration)	.133		8.873	.004
(2)	Question 2 (first Administration) Group	.187	.054	6.849	.002
(3)	Question 2 (first Administration) Group FOCHP	.249	.062	6.638	.000
(4)	Question 2 (first Administration) Group FOCHP SOCHP	.312	.063	6.789	.000

Overall Statistics

Variable	Beta	T	Sig T
FQ2	-.225278	-1.824	0.0745
GROUP	.314117	2.597	0.0125 *
FOCHP	-.297435	-2.492	0.0163 *
SOCHP	.272676	2.326	0.0244 *
(Constant)		0.197	0.8445

The groups explained another 5% of the variance; FOCHP, another 6%; and SOCHP, another 6%. Thus there was some limited evidence for the utility of both first and second order cognitive processes in effecting far transfer.

Conclusions

The instruction examined in this study produced gains in the capacity to engage in far transfer. While group membership, prior knowledge and FOCHP contributed to these gains, there was also evidence that SOCHP was also effective. The study has therefore provided some limited support for the relationships between gains in handling transfer tasks and the use of first and second order procedures during instruction. Thus, the results

provide some support for the hypothesis, *that the greater use of second order cognitive procedures in the class setting, will produce a greater success rate in completing a task requiring far transfer skills.*

As indicated above, the weaknesses of the study include the differing backgrounds of students entering groups, and the limitations of the instrument used to measure near and far transfer. It was not possible to know to what extent the instrument measured gains actually attributable to the use of second order procedures. Assessment instruments that require students to use far transfer techniques in formulating solutions, are not common in TAFE. Rather, assessment within the CBT framework tends to be related to testing whether the learner can replicate a series of prescribed specific procedures. Thus, the development of instruments that challenge the learner to use second order procedures is not a simple task for many teachers. Further research will need to be undertaken to assist in the development of appropriate testing instruments and the determination of their validity and reliability.

Australian vocational education is charged with the responsibility of producing adaptable workers, able to confront the changes taking place in their workplace (See also Chapter 5). Thus, the challenge for teachers and trainers is to ensure that students become adaptable as a natural part of their skills acquisition. To date there has been very little guidance for teachers on teaching for adaptability and the learning conditions that would support its acquisition. Current research is identifying the cognitive structures involved in adult and vocational education and in particular those which are involved in adaptation. Further research will identify ways in which they might be further developed.

Research recently undertaken by Stevenson and McKavanagh (1993) in the Queensland TAFE setting showed distinctive Cognitive Holding Power (CHP) differences between theory and practical settings (See also Chapter 6). Theory classes tended to be teacher-centred, with the whole class action focused on information from spoken words and text. Two thirds of the time in theory classes was devoted to content consisting of information. As such, there is almost no emphasis on procedural and intellectual skills as it is the teacher, rather than the learner, doing the higher thinking. Students were engaged in shallow thinking, or First Order CHP. In contrast, their research indicated that practical classes had the greater diversity of

activities, these activities centring preliminary more on individuals and small groups, supported by the teacher. These practical settings were more likely to encourage students to tackle problems themselves and ask for help when needed, and more likely to encourage second order CHP. Clearly, when the teacher initiates the action, or when there is substantial presentation, learners engage in lower order thinking. It appears that the learning strategies adopted by the teacher, more than any other factor, may have most influence on CHP.

In Queensland the move toward a lecture/tutorial mode of delivery needs to be carefully considered by teachers. Implemented appropriately, it has a capacity to reduce the time teachers spend in information giving, by ensuring that the lecture component is minimal, and problematic questions are posed for students to solve in the smaller learner-centred tutorials. Implemented purely as a method of putting more students in front of teachers, it could pose a serious threat for the cognitive development of learners.

It may be that the move toward government and industry intervention into curriculum development is more a desire to influence what needs to be taught, and how flexibly it might be delivered. TAFE teachers need to respond to these challenges by ensuring that the methodologies they adopt, in response, do in fact improve teaching and learning practices. The focus in CBT has tended to be on learning outcomes, often at the expense of learning processes. Whatever educational delivery system is fashionable, whether imposed or through choice, teachers need to develop, within that system, learning strategies that are in the best interests of learners and are based on theoretical principles.

The measurement of cognitive holding power should help to increase teachers' awareness of the kinds of cognitive activity in which learners are engaging and the kinds of structures which are being developed. This awareness should enable teachers to evaluate better the instructional strategies they employ and assist them further in implementing curricula. This study has provided some preliminary, but limited, evidence of the effectiveness of Second Order Cognitive Holding Power in developing the adaptability needed in work.

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